

WIMP dark matter and the isotropic radio background connection

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Outline

Introduction

Cosmic ray propagation

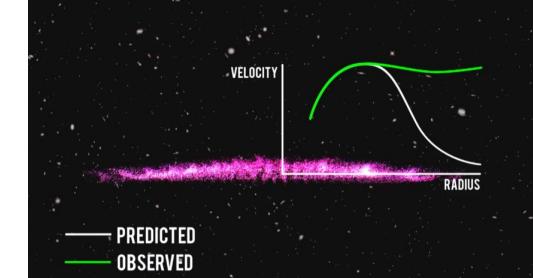
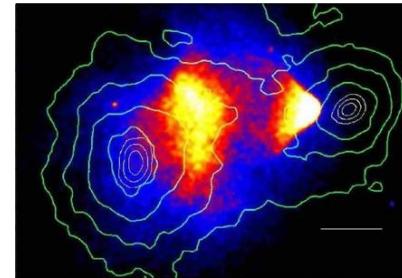
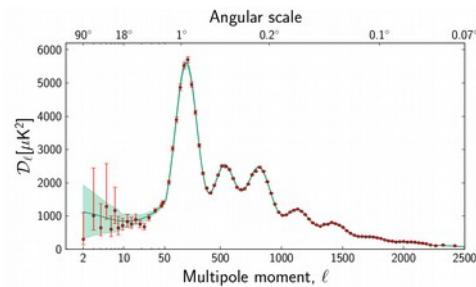
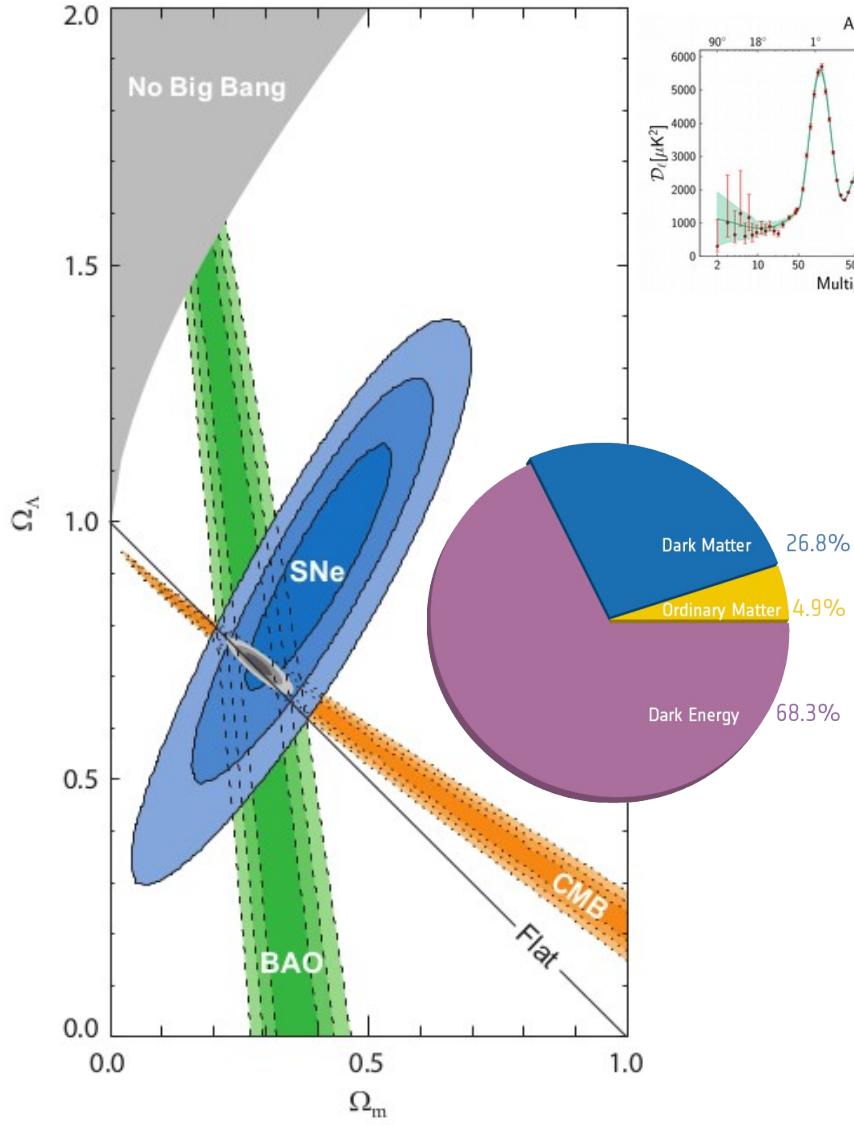
Synchrotron emission

WIMPs @ Radio
- galactic
- extragalactic

Conclusions



Dark Matter

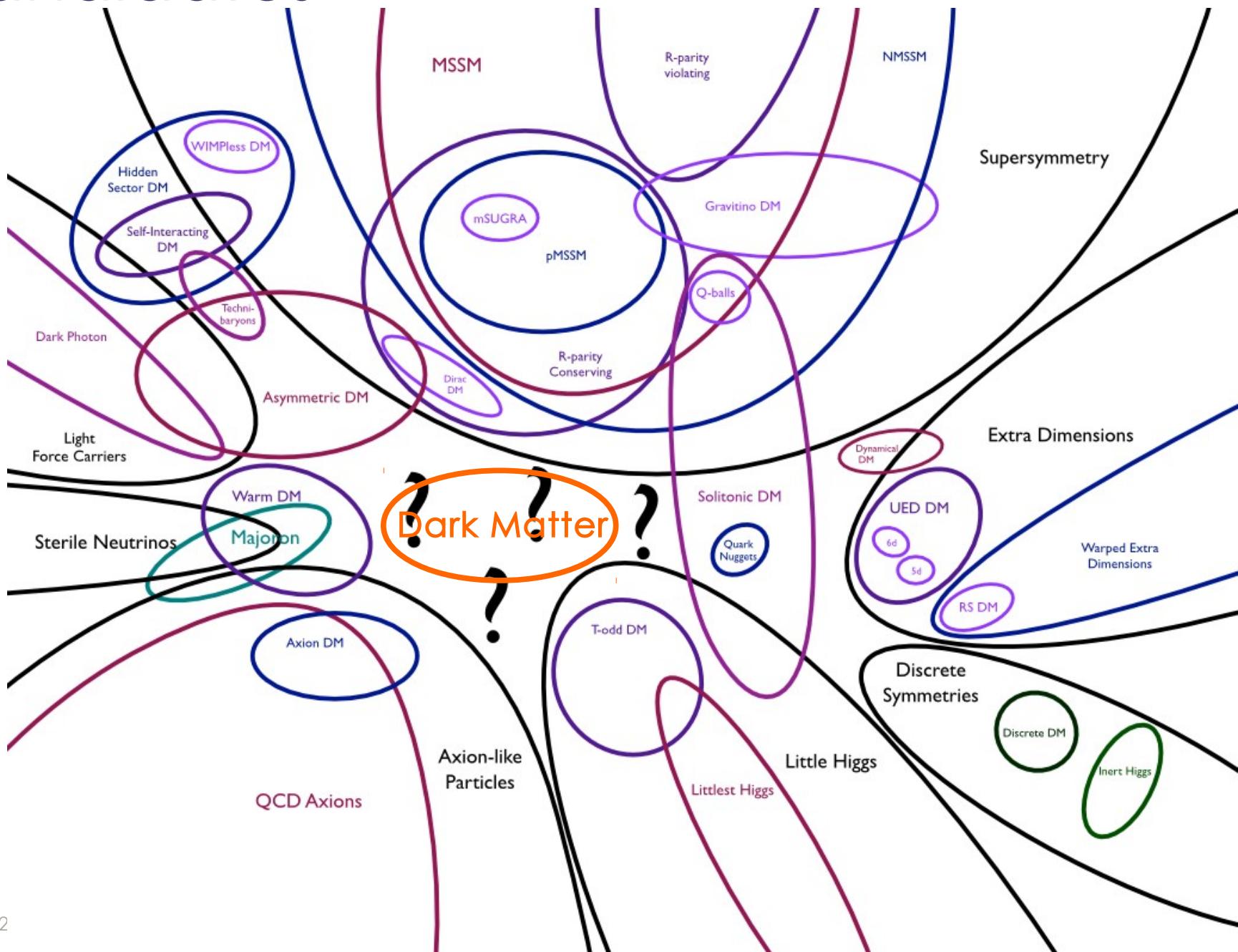


Observations support **Dark Matter** at:

Galactic scales
Galaxy clusters scales
Cosmological scales

$$\Omega_{\text{DM}} h^2 = 0.1196 \pm 0.0031$$

Candidates

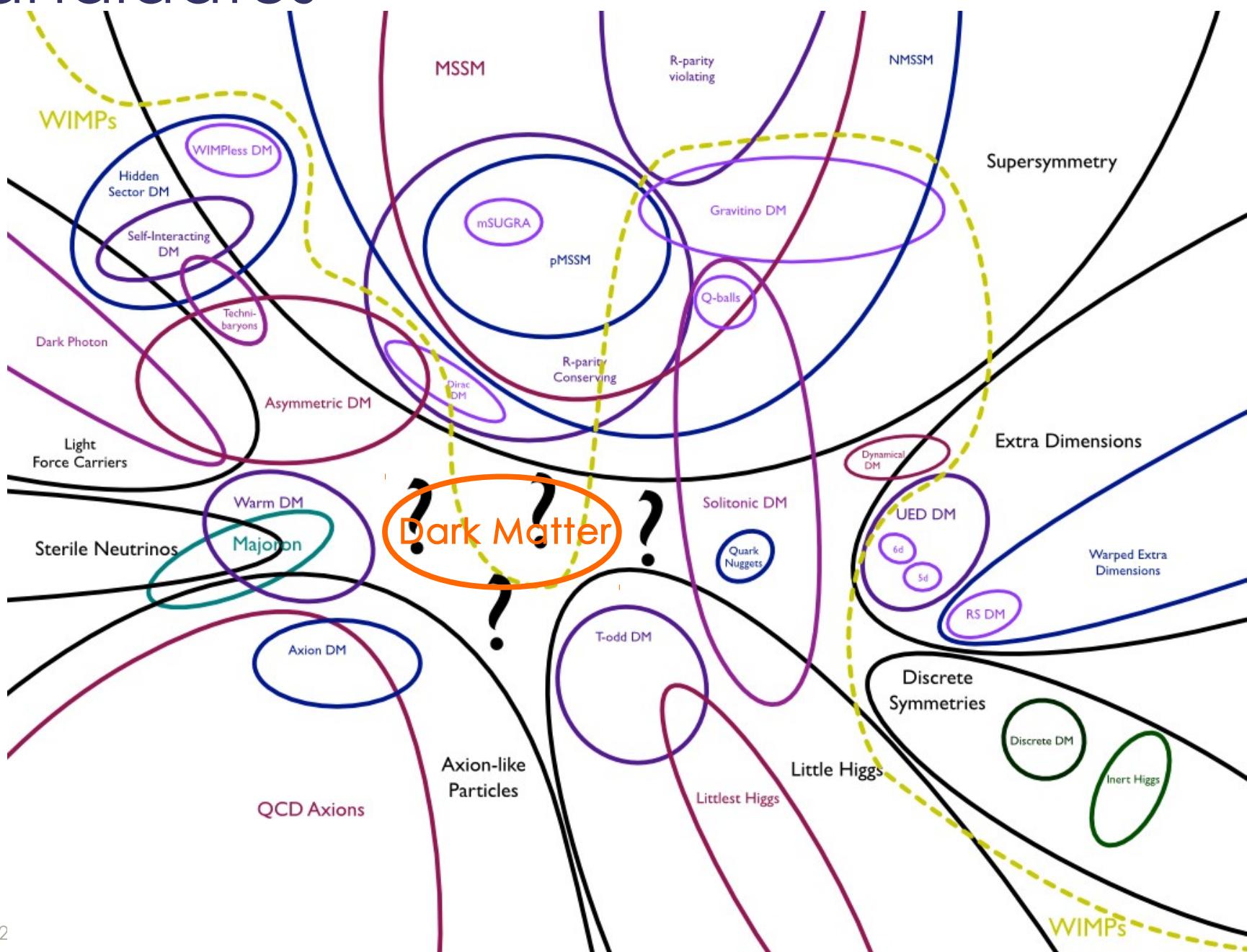


Adapted from arxiv:1401.6085

WIMPs

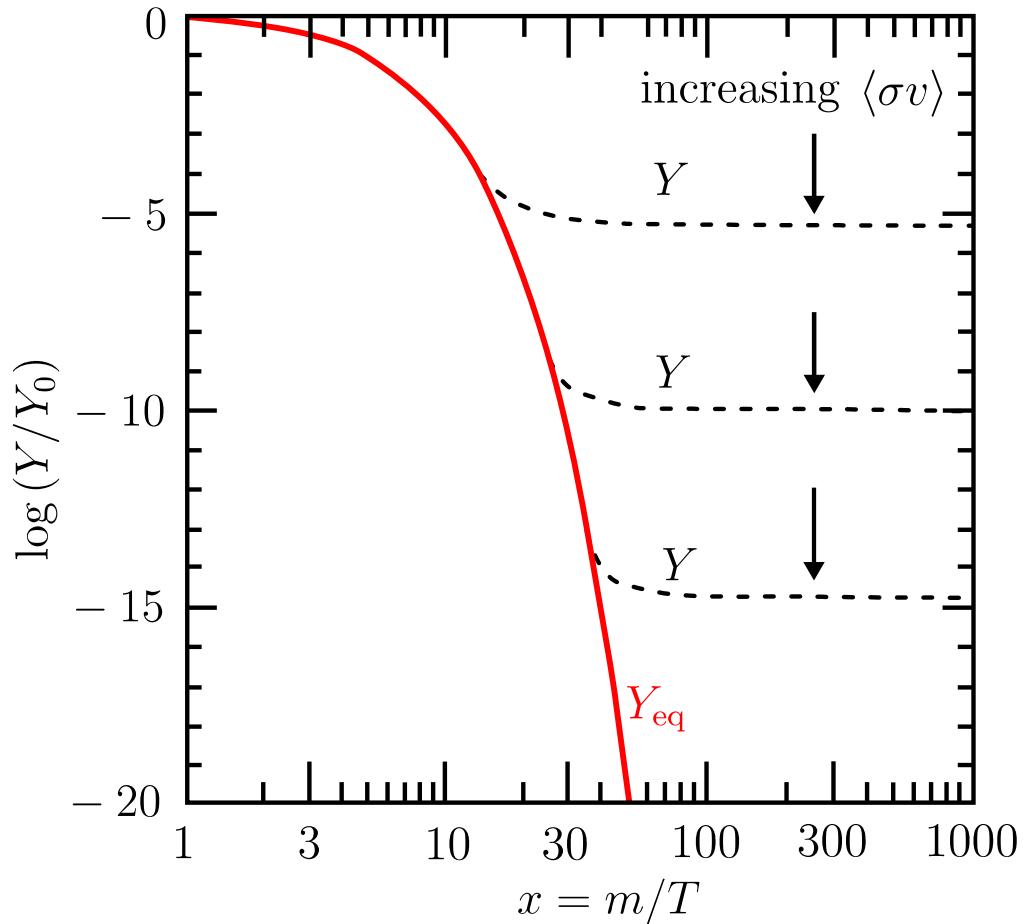
Weakly Interactive Massive Particles

Candidates



Adapted from arxiv:1401.6085

WIMPs



Big Bang Thermal relic

Correct relic abundance
for $\langle\sigma v\rangle \sim 1 \text{ pb} \cdot c$

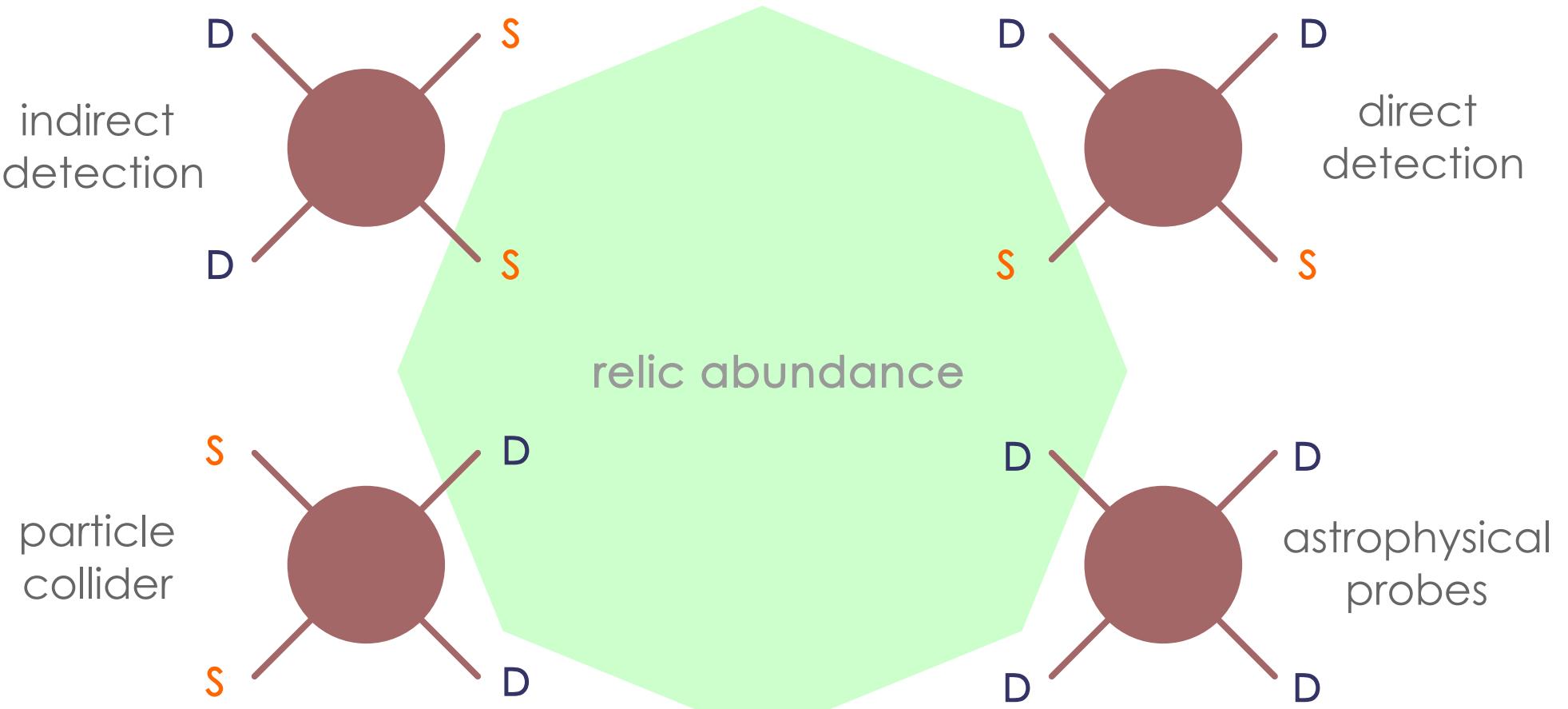
Mass in GeV-TeV range

For WIMPs:

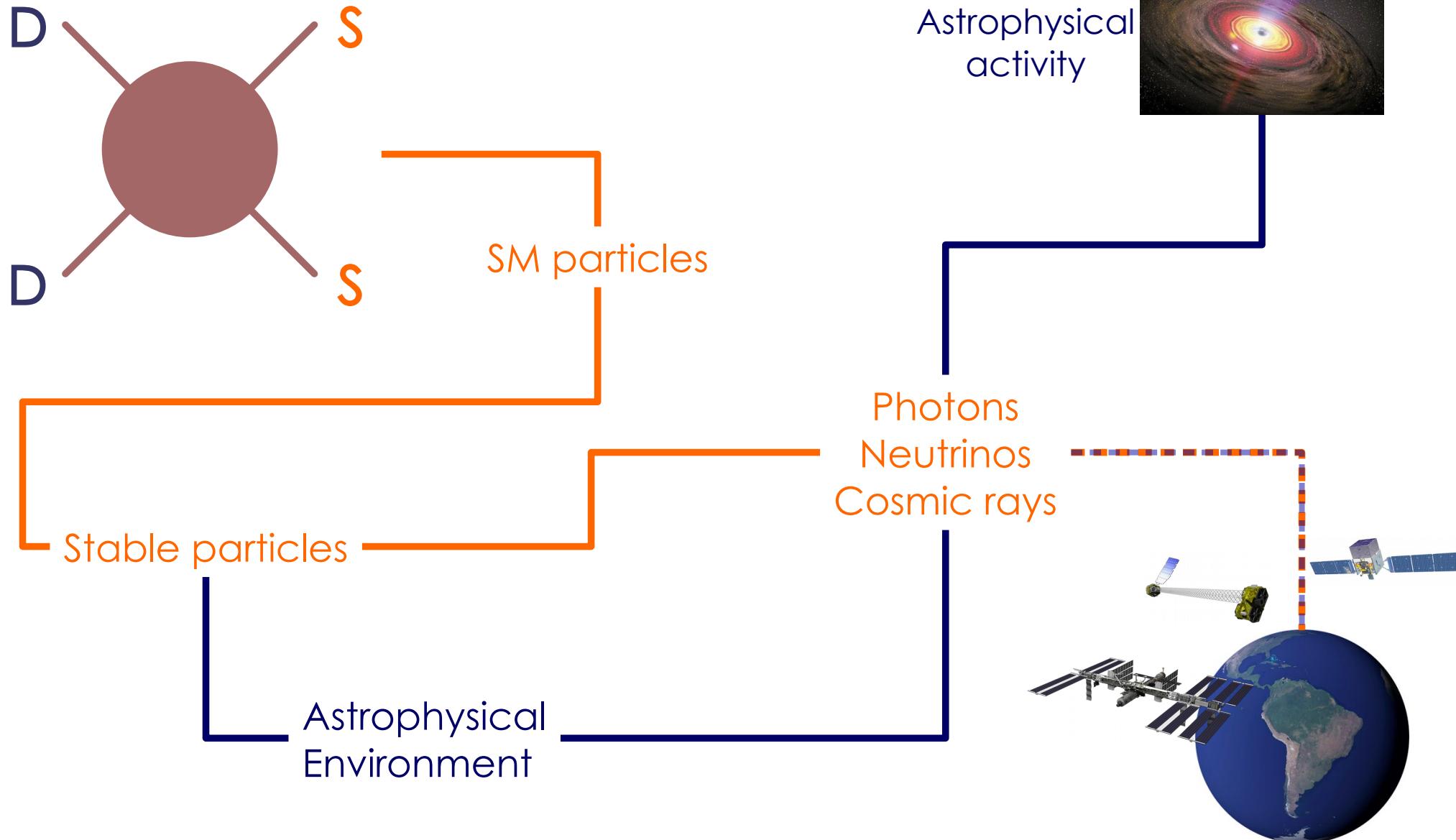
$$\Omega_{\text{DM}} h^2 \simeq 0.1 \frac{3 \times 10^{-26} \text{ cm}^3/\text{s}}{\langle\sigma v\rangle_{\text{f.o.}}}$$

$$T_{\text{DM}}^{\text{f.o.}} \simeq \frac{1}{20} m_{\text{DM}}$$

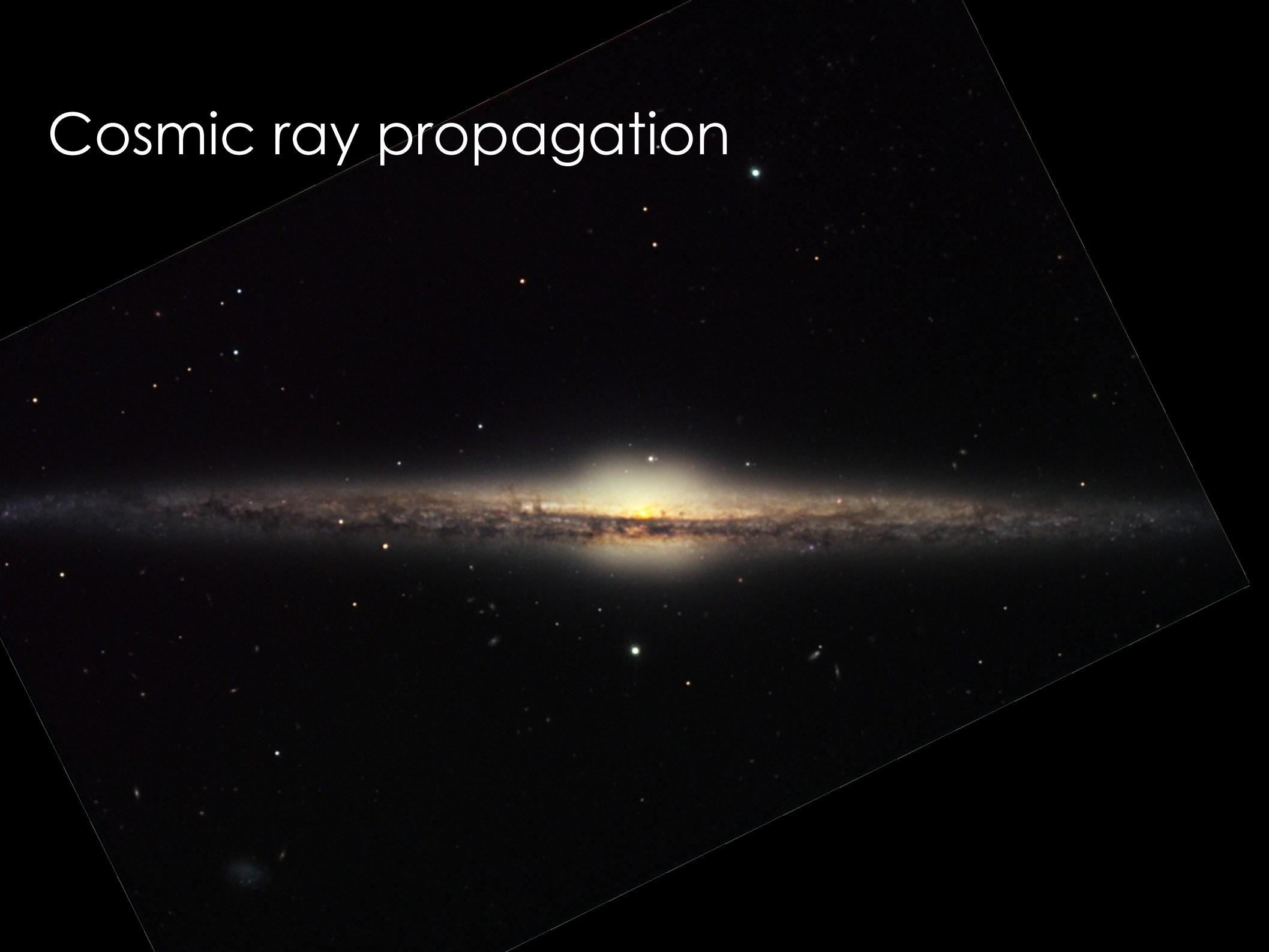
WIMP Searches



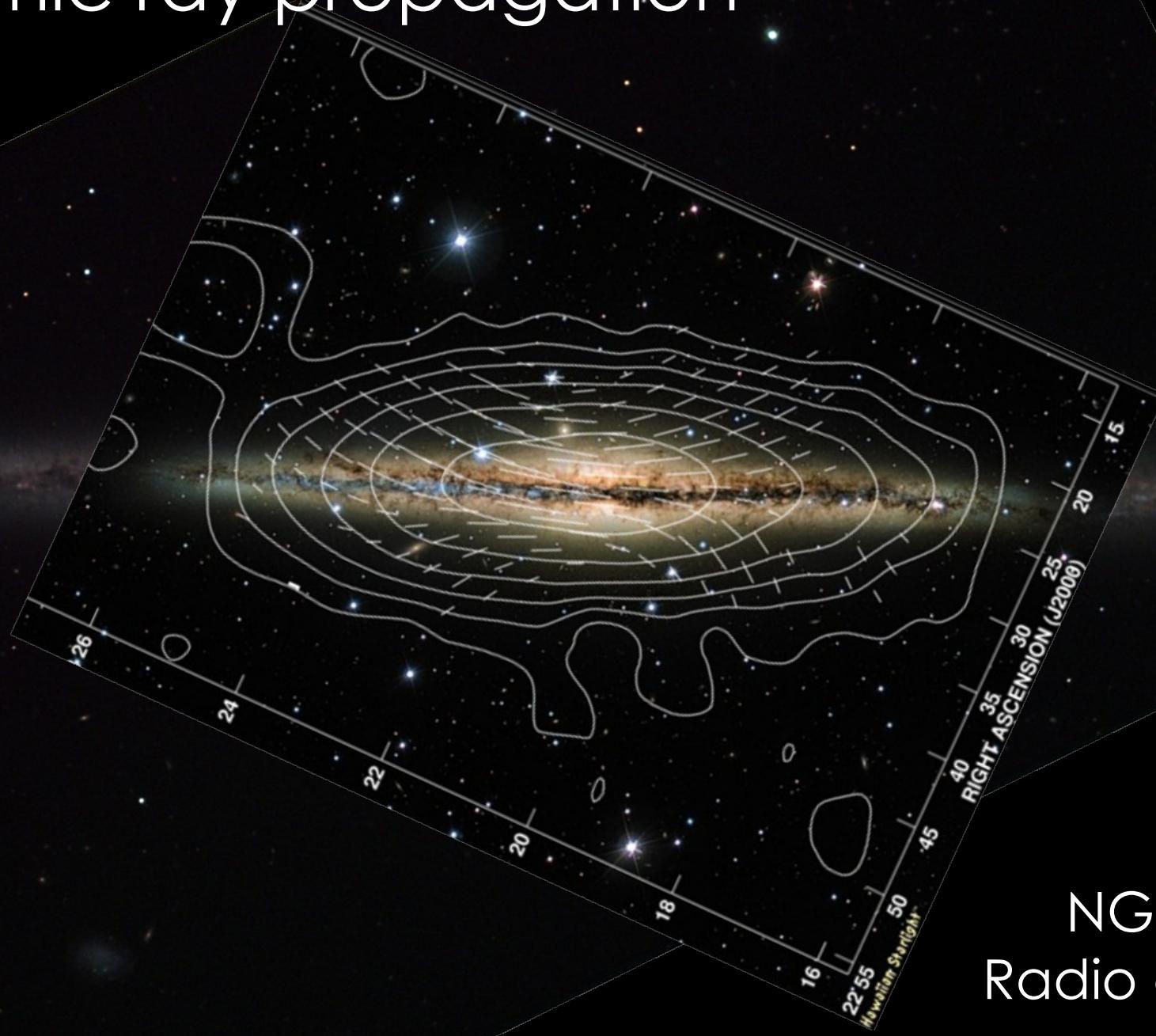
Indirect DM search



Cosmic ray propagation

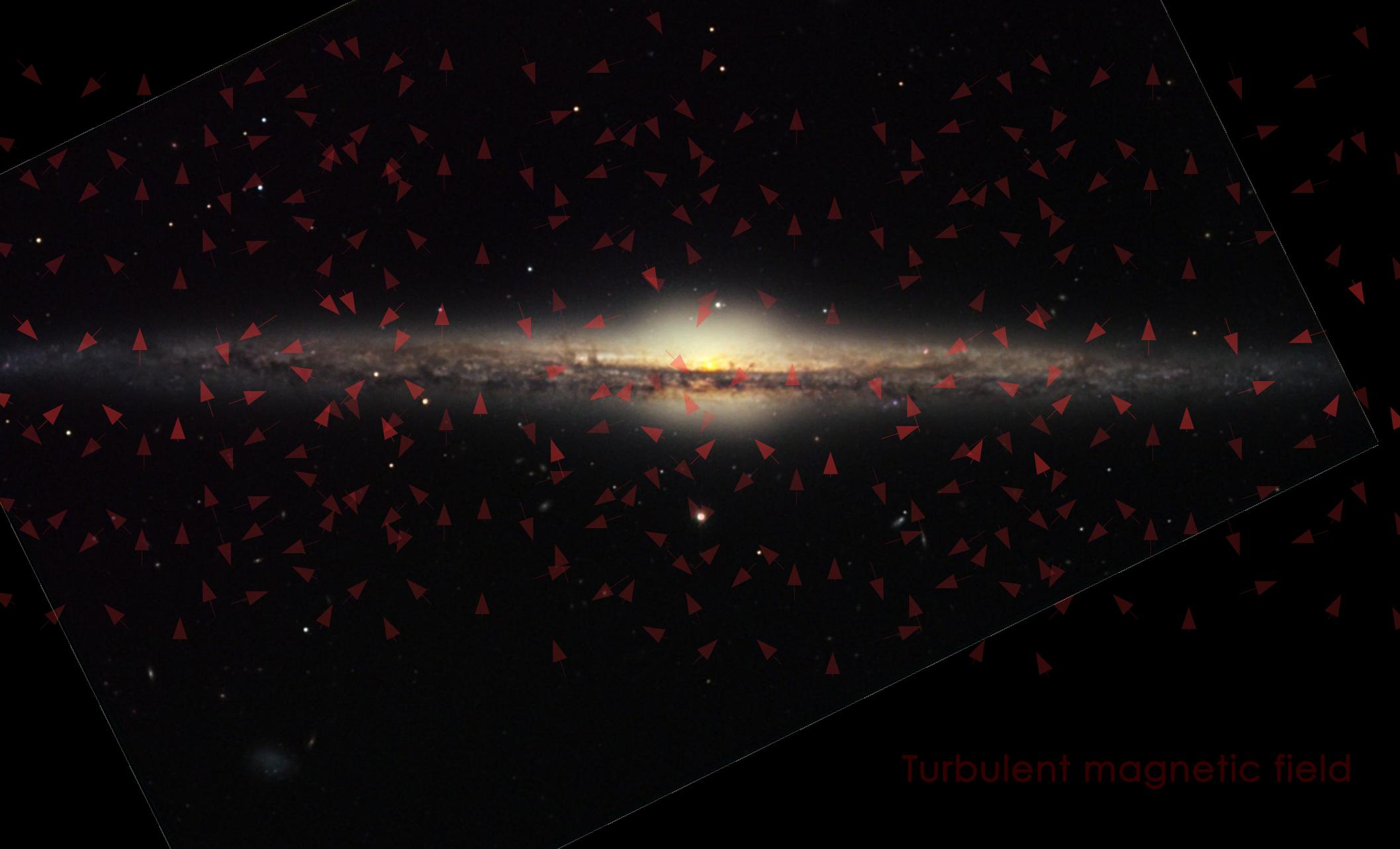


Cosmic ray propagation

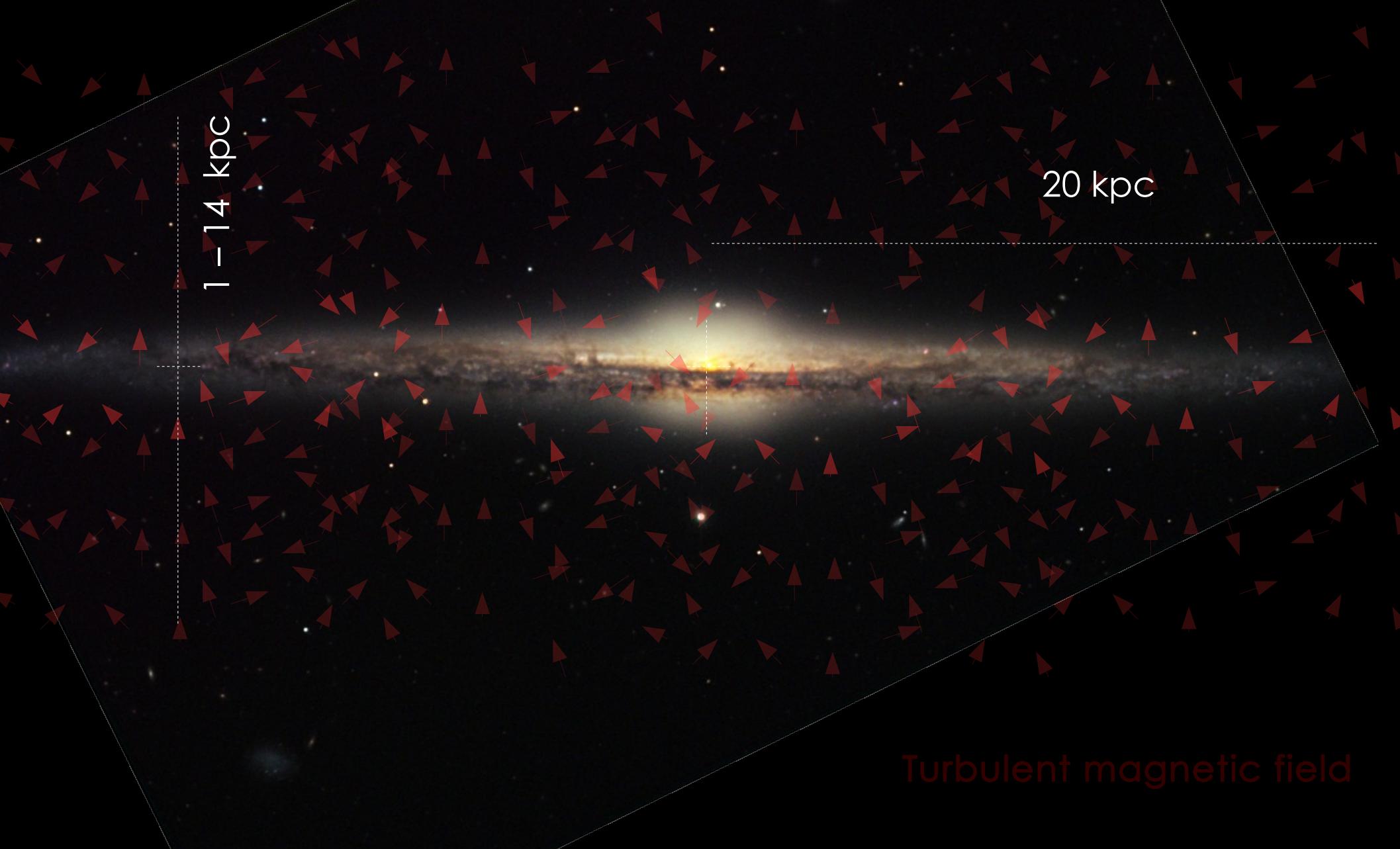


NGC891
Radio emission

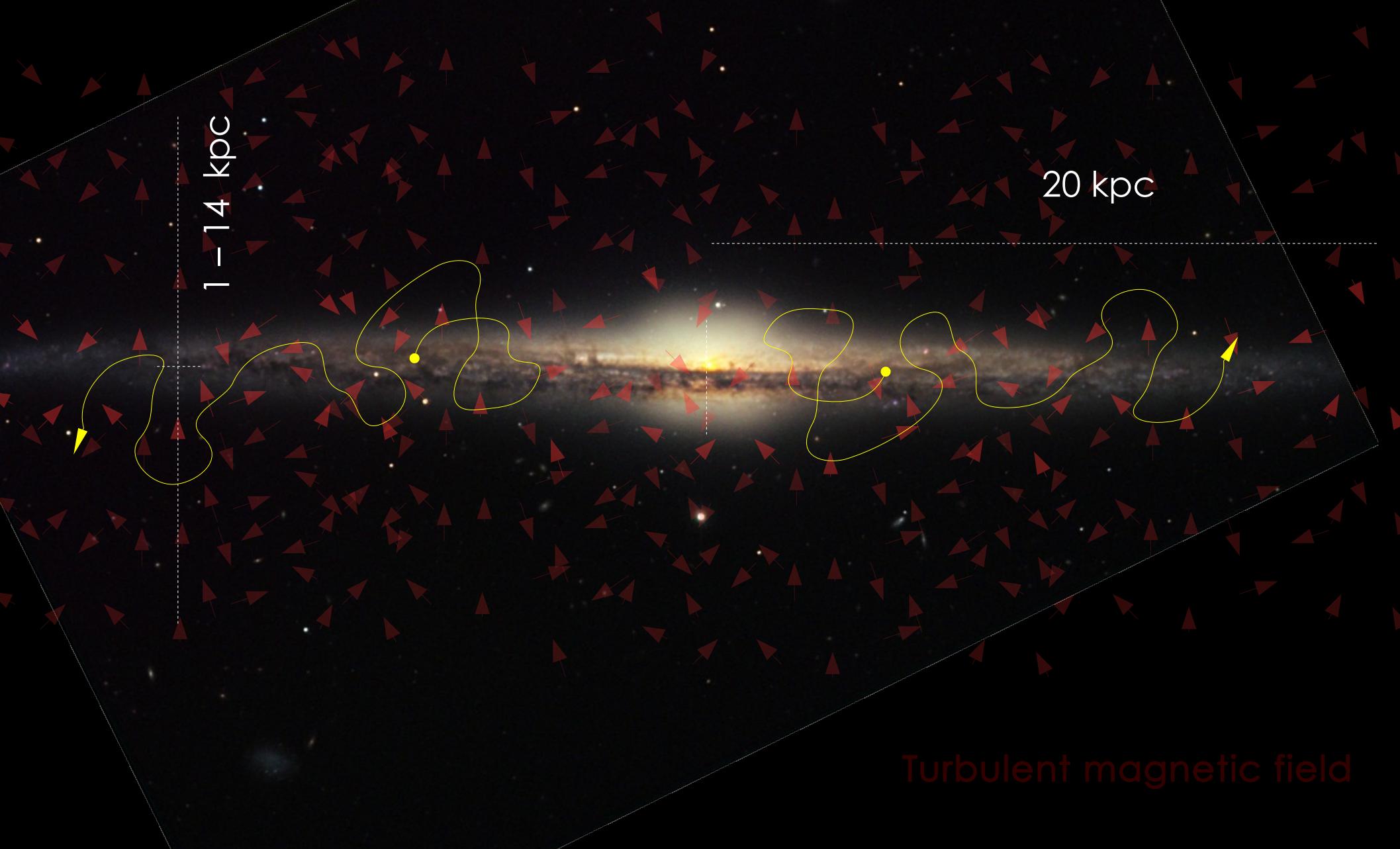
Cosmic ray propagation



Cosmic ray propagation



Cosmic ray propagation



Cosmic ray propagation

The **transport equation** describes the evolution of the density of cosmic rays

$$\frac{\partial \psi}{\partial t} + \nabla \cdot (-K_0 \epsilon^\delta \nabla \psi + \mathbf{V}_c \psi) + \frac{\partial J_\epsilon}{\partial \epsilon} = q_{\text{src}}$$

Time evolution

Diffusion

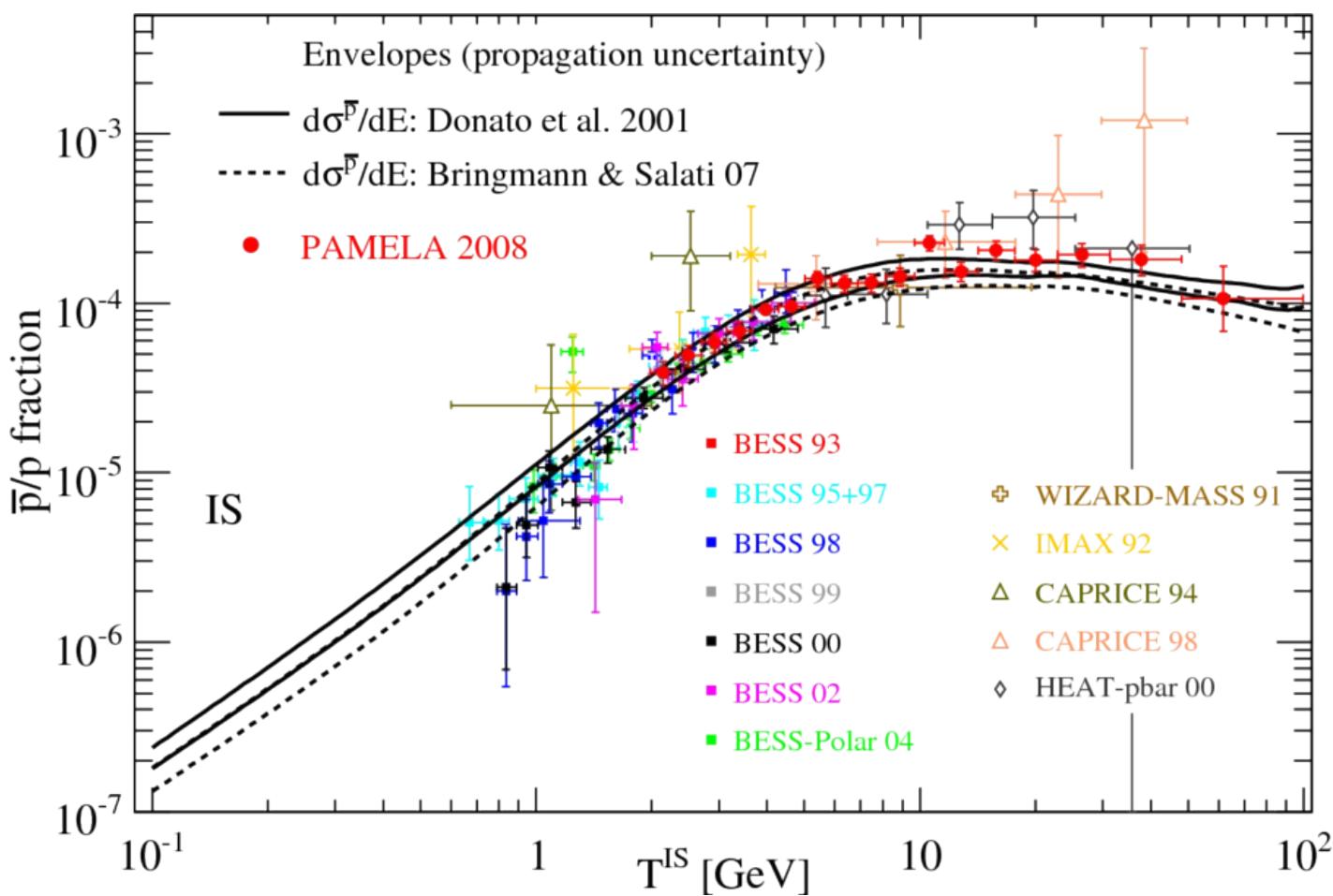
Convection

Energy evolution

Sources

Each species has its own transport equation
usually coupled with other CR specie

Cosmic ray propagation



Mod.	prop. parameters		
	L [kpc]	K_0 [$\frac{kpc^2}{Myr}$]	δ
min	1	0.0016	0.85
med	4	0.0112	0.70
max	15	0.0765	0.46

There is some degeneracy in the propagation's parameter space

Cosmic ray propagation

Transport equation

$$\frac{\partial \psi}{\partial t} + \nabla \cdot (-K_0 \epsilon^\delta \nabla \psi + \mathbf{V}_c \psi) + \frac{\partial J_\epsilon}{\partial \epsilon} = q_{\text{src}}$$

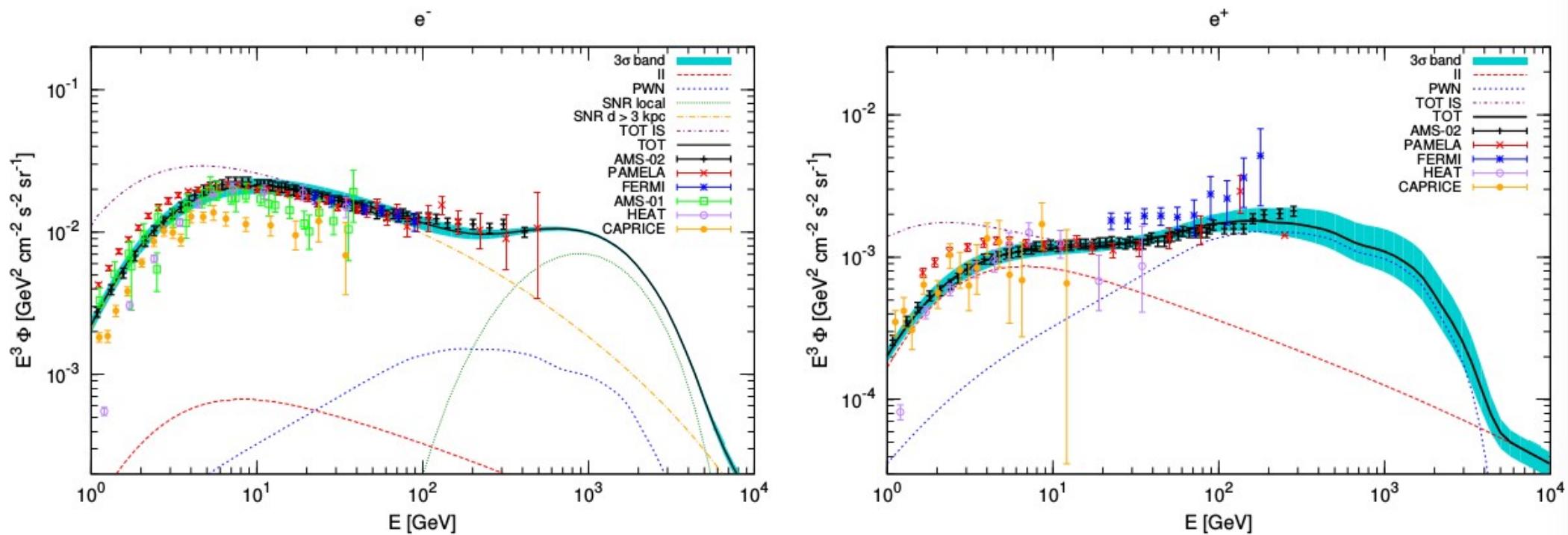
Secondaries
From spallations

$$q_{e^\pm}(\mathbf{x}, E_e) = 4\pi n_{\text{ISM}}(\mathbf{x}) \int dE_{\text{CR}} \Phi_{\text{CR}}(\mathbf{x}, E_{\text{CR}}) \frac{d\sigma}{dE_e}(E_{\text{CR}}, E_e)$$

Primaries
From SNR and pulsars

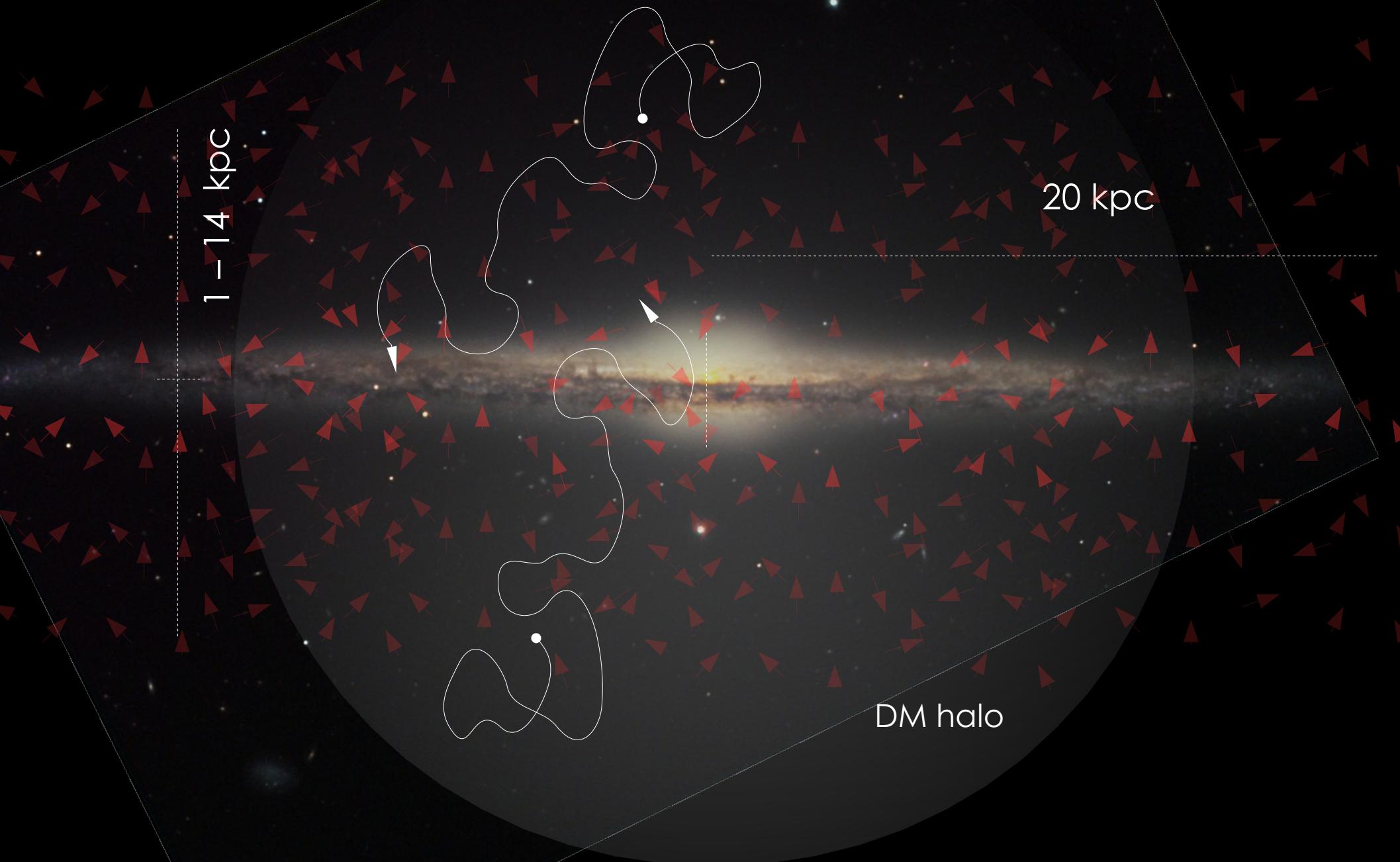
$$\left\{ \begin{array}{l} \mathcal{Q}(E) = \mathcal{Q}_0 \epsilon^{-\gamma} \exp \left\{ -\frac{E}{E_c} \right\} \\ \rho(r, z) = \rho_0 r^a \exp \left\{ -\frac{r}{r_0} \right\} \exp \left\{ -\frac{|z|}{z_0} \right\} \end{array} \right.$$

Cosmic ray propagation



Details in arxiv:1402.0321

Cosmic ray propagation



Cosmic ray propagation

Transport equation

$$\frac{\partial \psi}{\partial t} + \nabla \cdot \left(-K_0 \epsilon^\delta \nabla \psi + \mathbf{V}_c \psi \right) + \frac{\partial J_\epsilon}{\partial \epsilon} = q_{\text{src}}$$

Source from
DM annihilation

$$q(\mathbf{x}, E) = \frac{1}{2} (\sigma v) \left(\frac{\rho(\mathbf{x})}{M_{\text{DM}}} \right)^2 \frac{dn}{dE}(E)$$

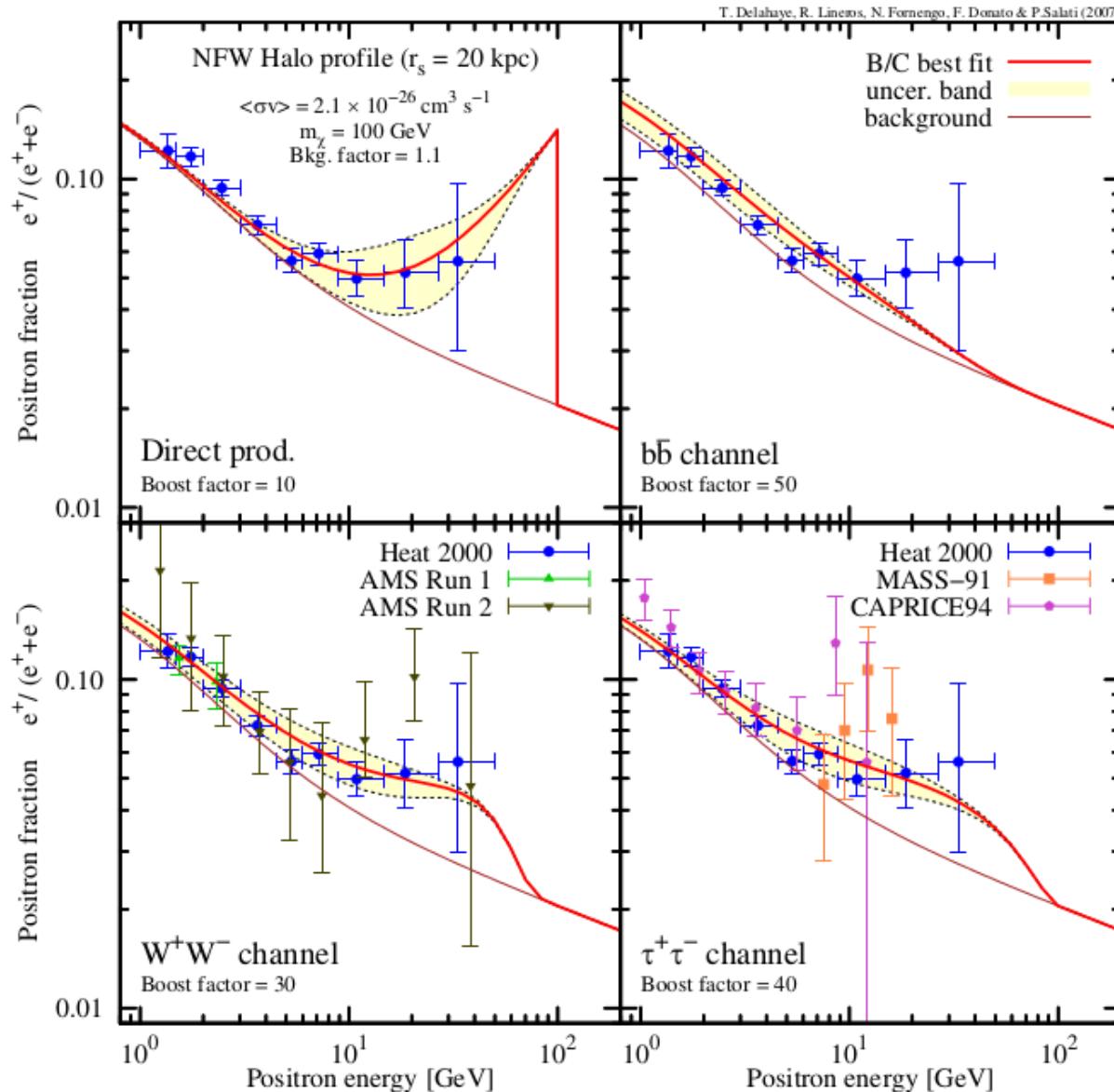
Annihilation cross section

Annihilation spectrum

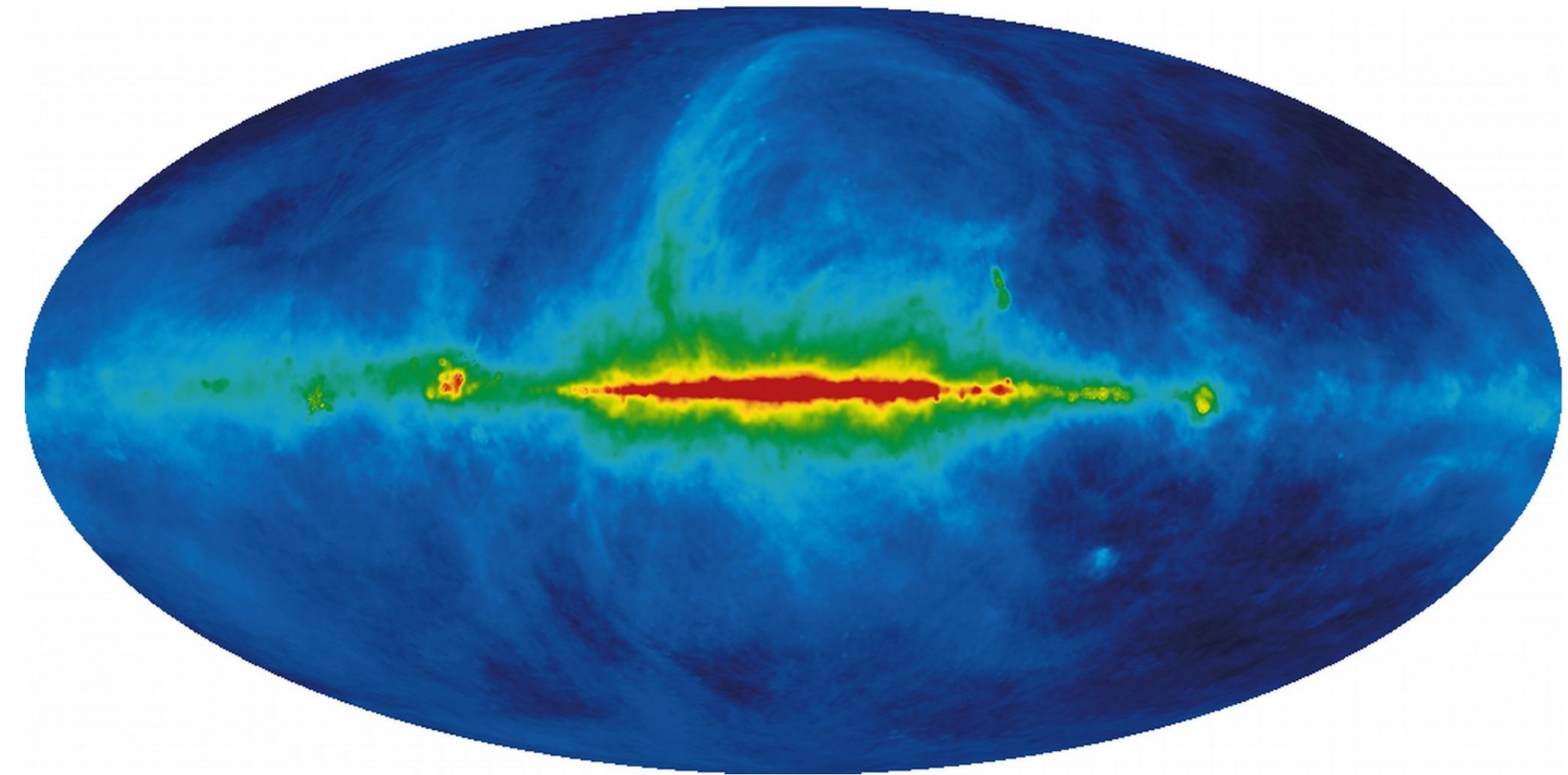
DM distribution

Cosmic rays propagation

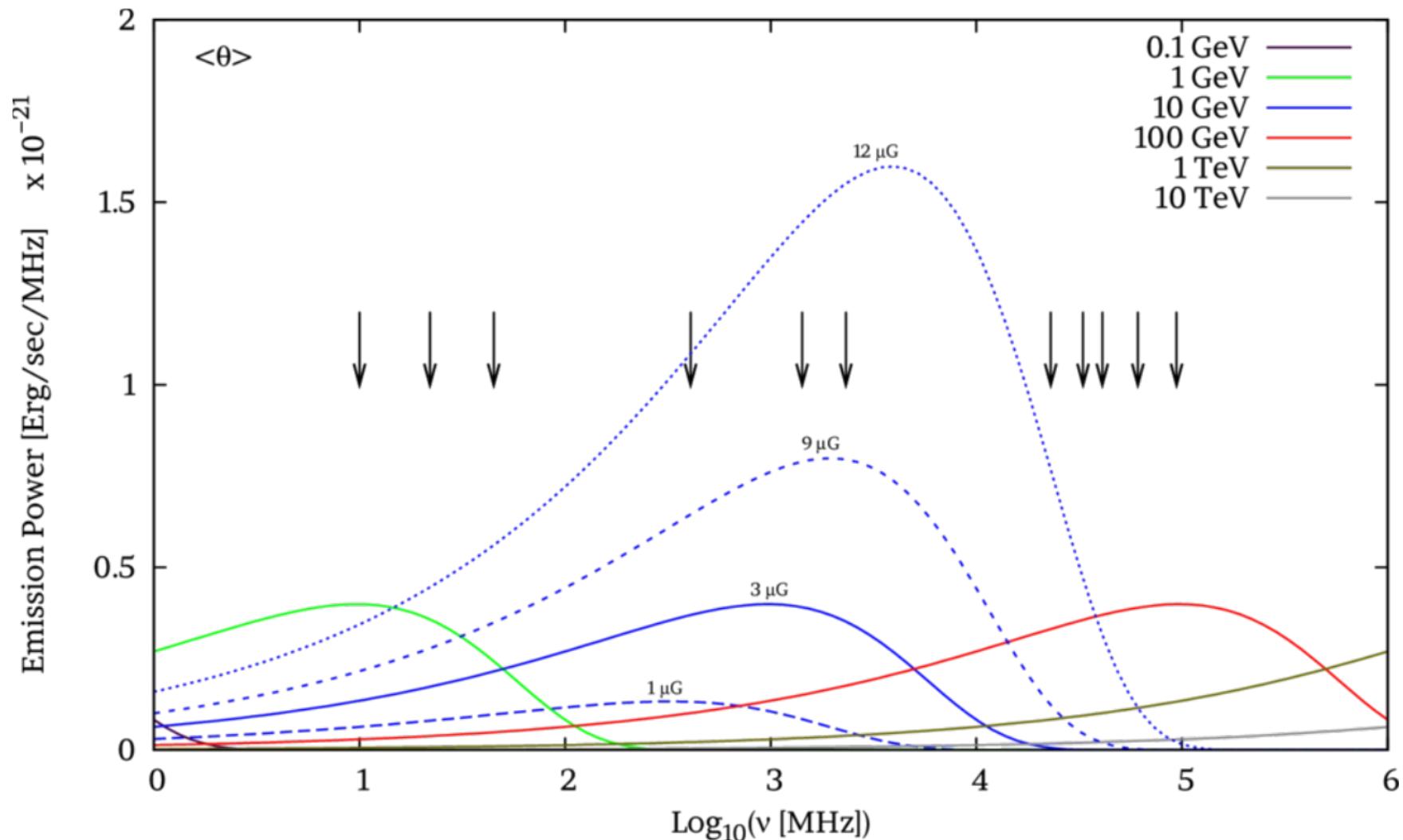
[arxiv:0712.2312]



WIMP Searches in radio



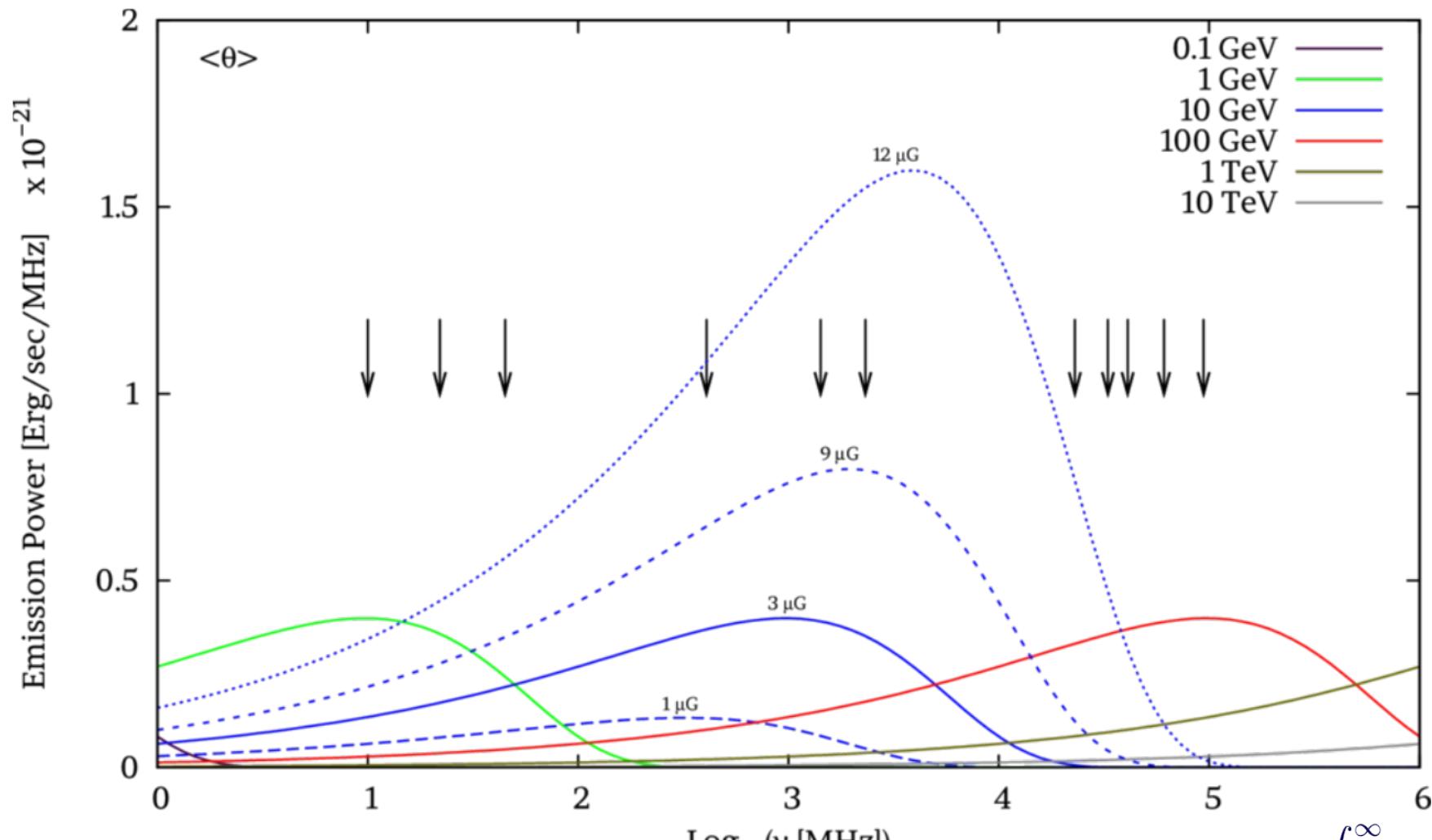
Synchrotron spectrum



Synchrotron spectrum

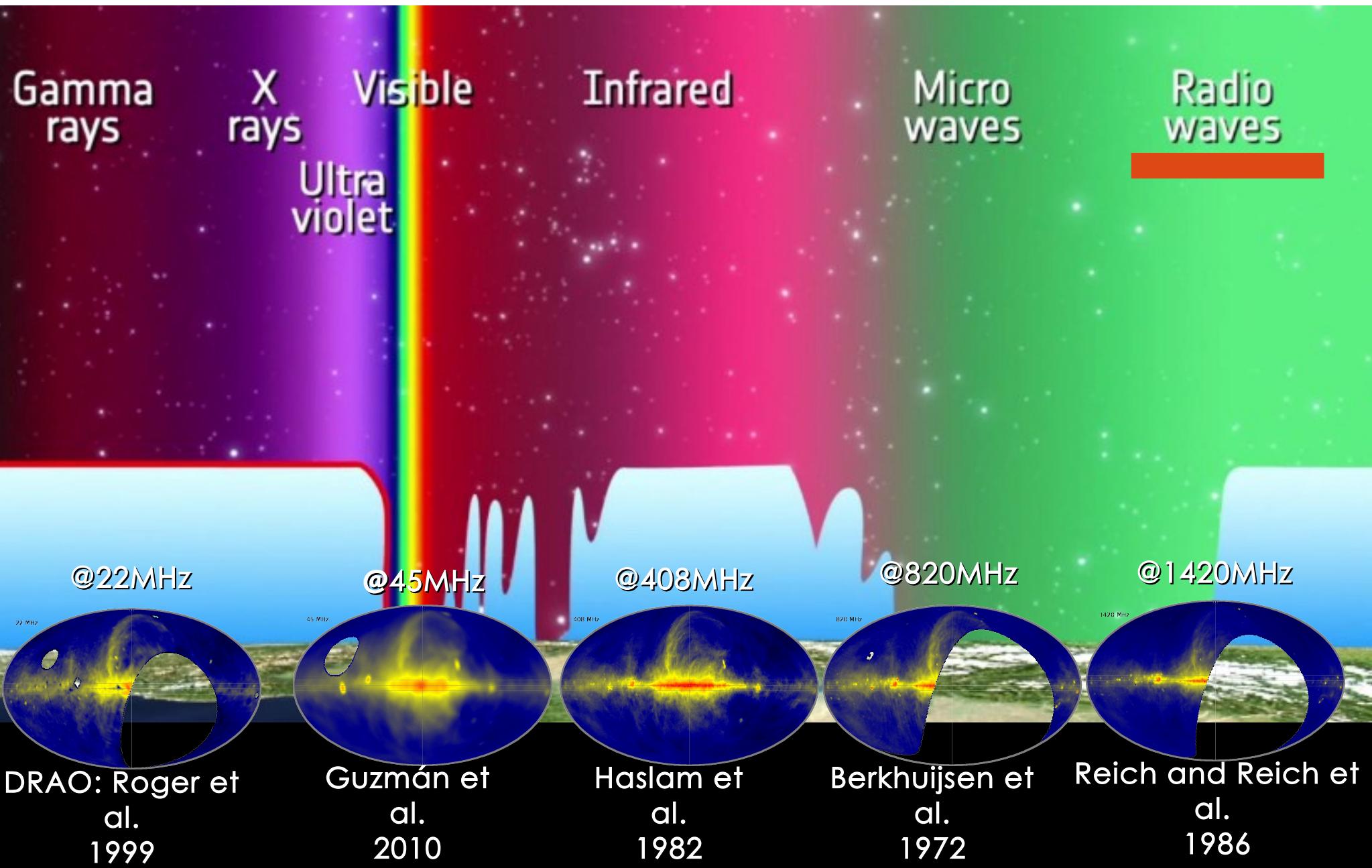
$$\frac{dw}{d\nu}(\nu, B_{\perp}) = \frac{\sqrt{3} e^3 B_{\perp}}{m_e c^2} F\left(\frac{\nu}{\nu_{c,\perp}}\right)$$

$$\nu_{c,\perp} = \frac{3eB_{\perp}E^2}{4\pi m_e^3 c^5}$$

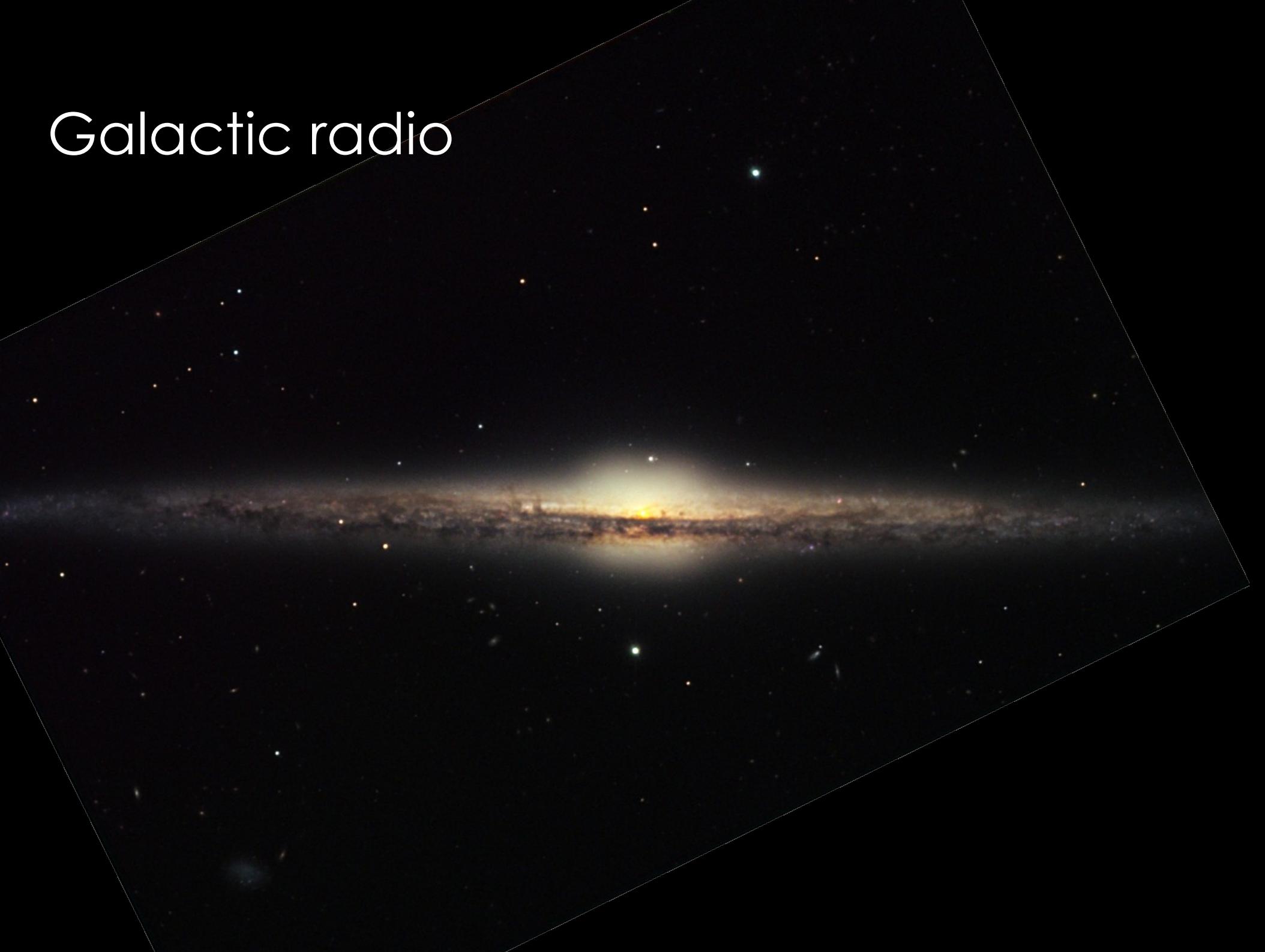


$$F(x) = x \int_x^{\infty} d\zeta K_{5/3}(\zeta)$$

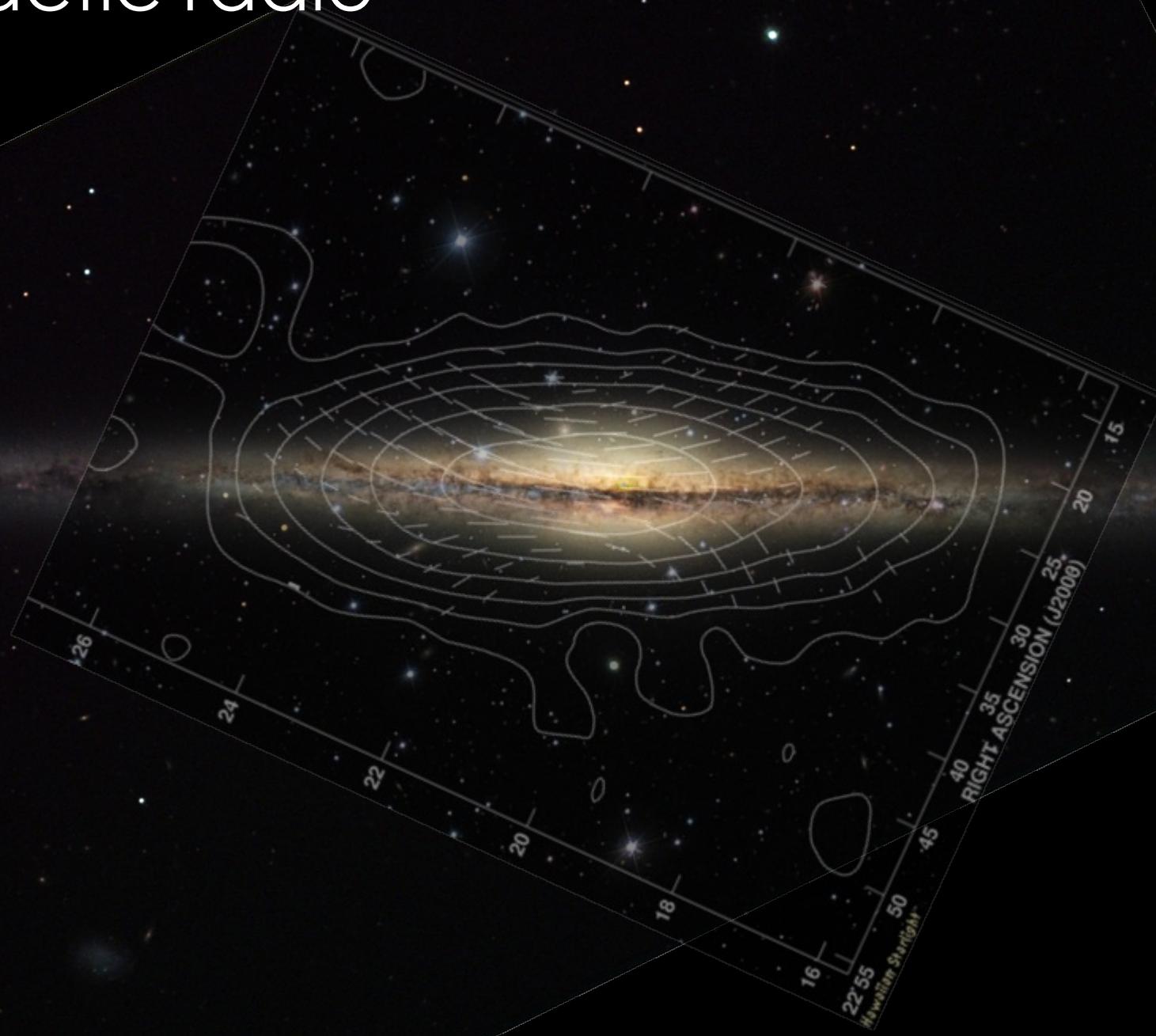
Observations from 22 to 1420 MHz



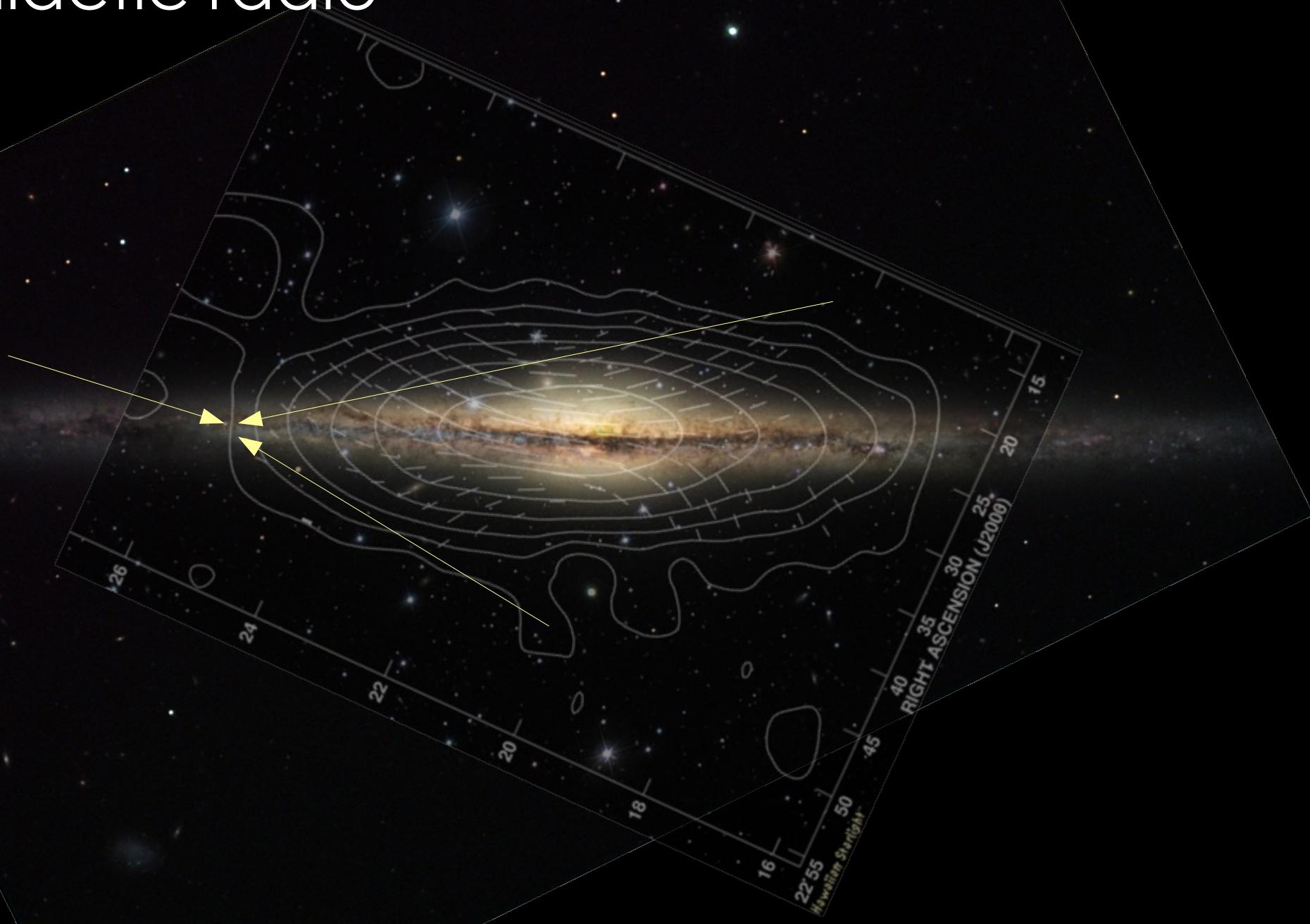
Galactic radio



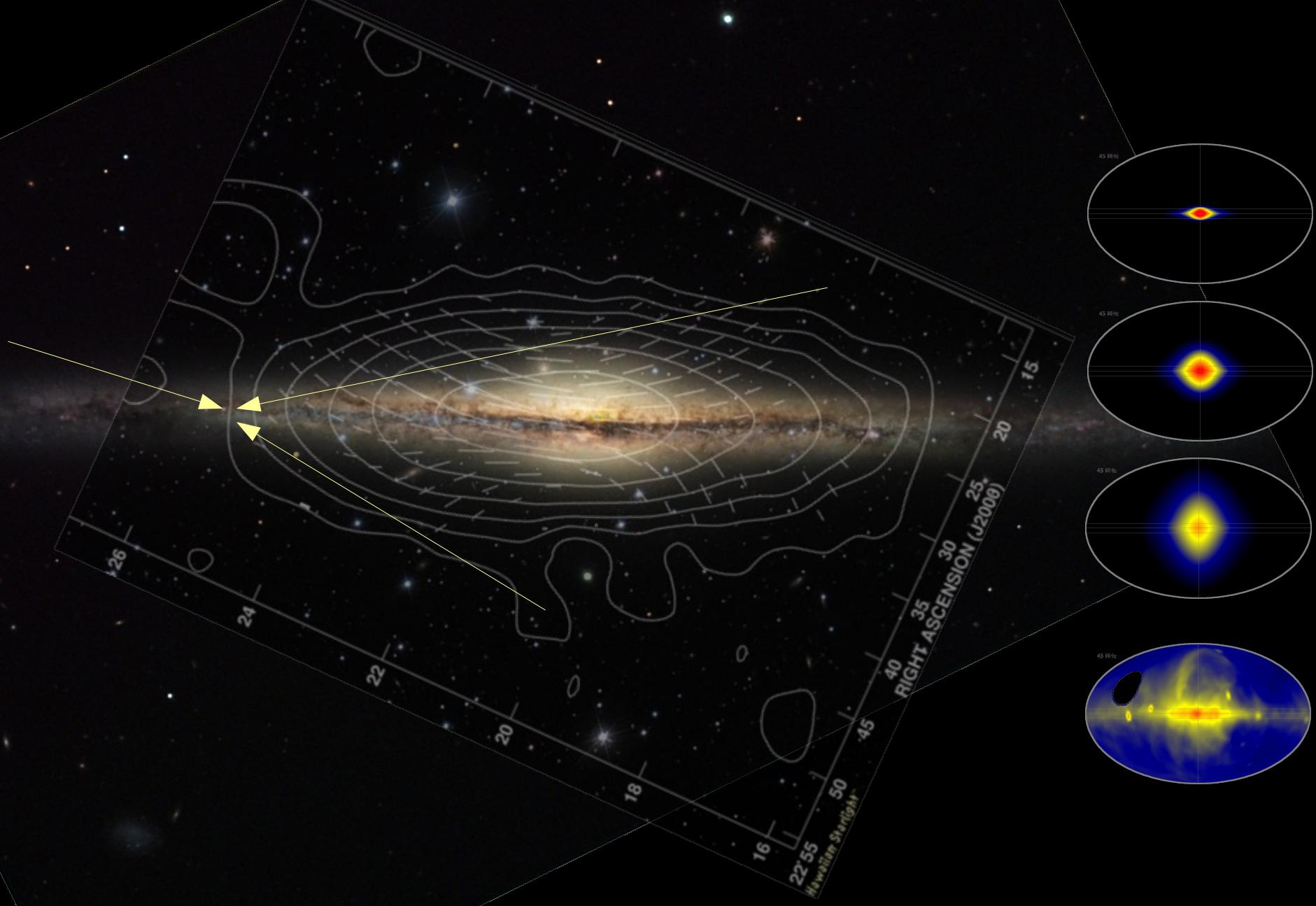
Galactic radio



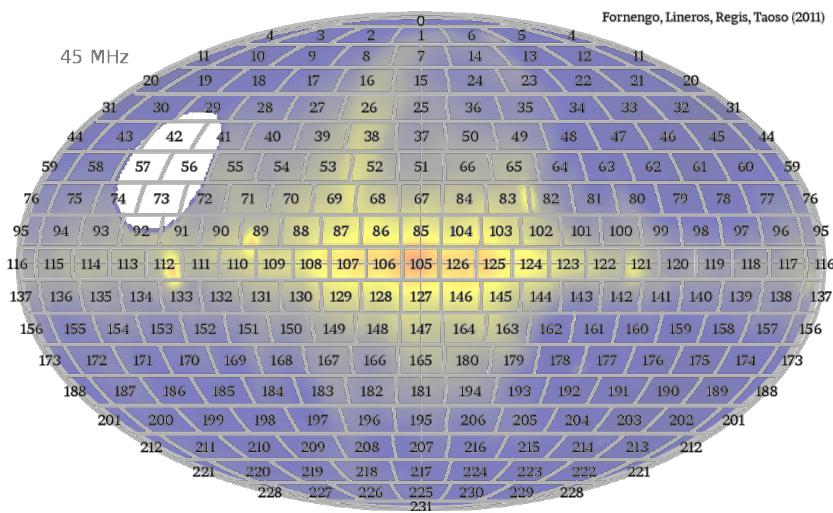
Galactic radio



Galactic radio

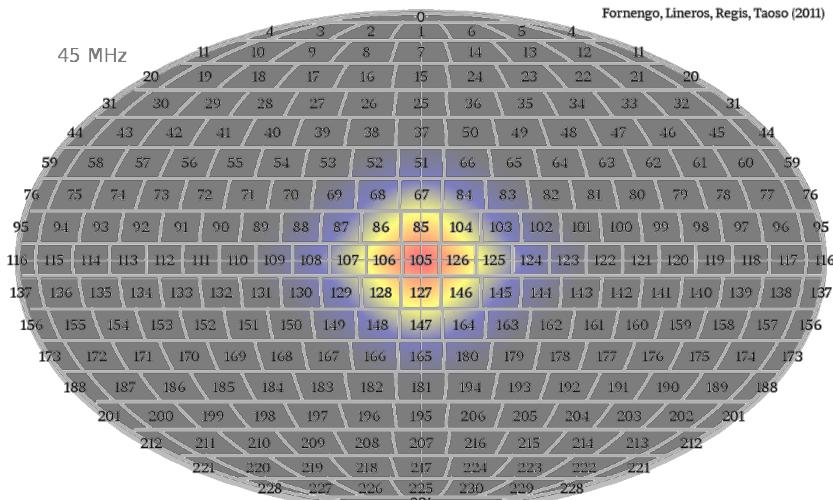


Constraining Galactic DM



We divide Obs & DM skymaps into several patches $\sim 10^0 \times 10^0$

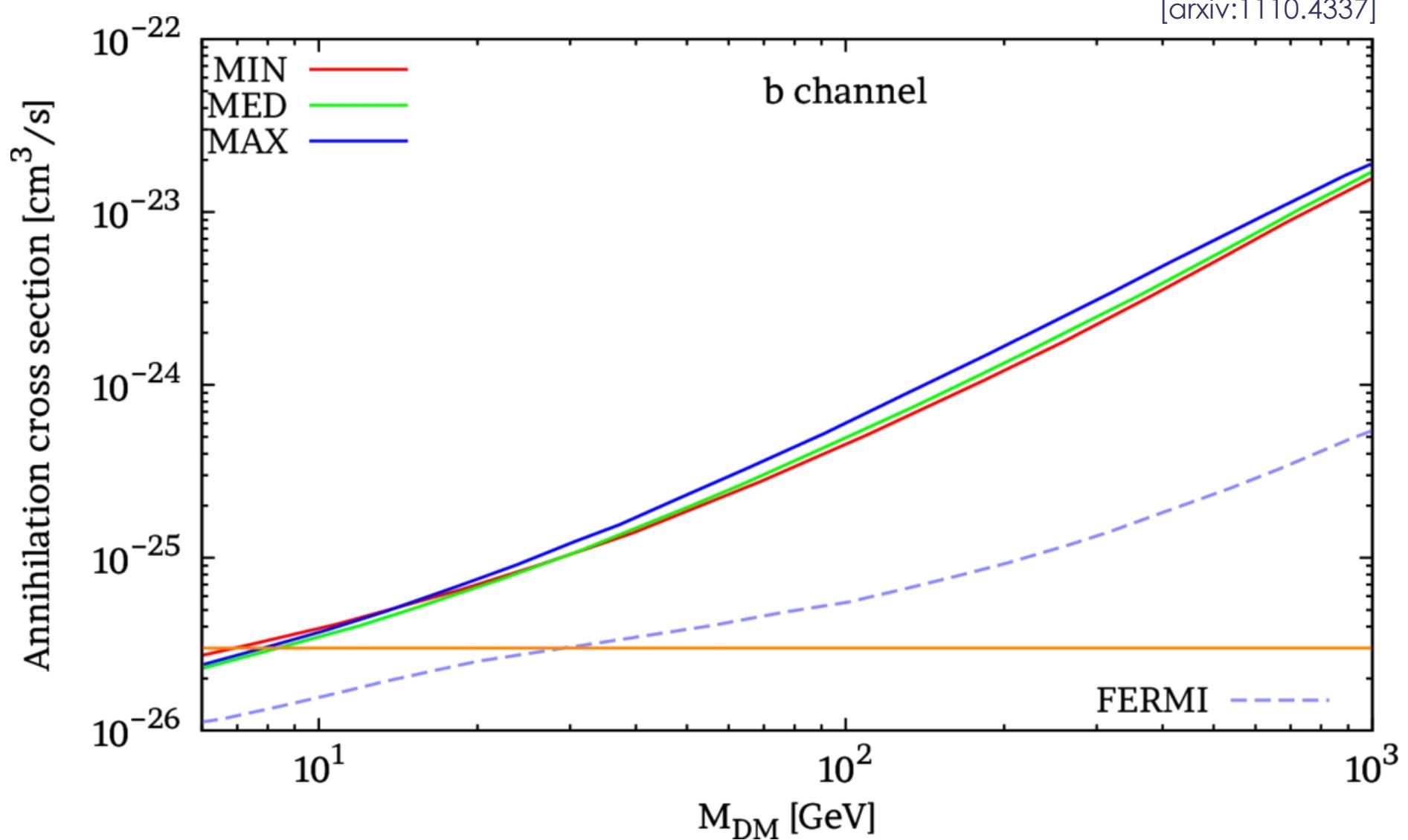
$$T_{\text{DM}} \leq T_{\text{obs}} + 3\sigma$$



We calculate an upper bound for (σv) using the most stringent patch in each skymap

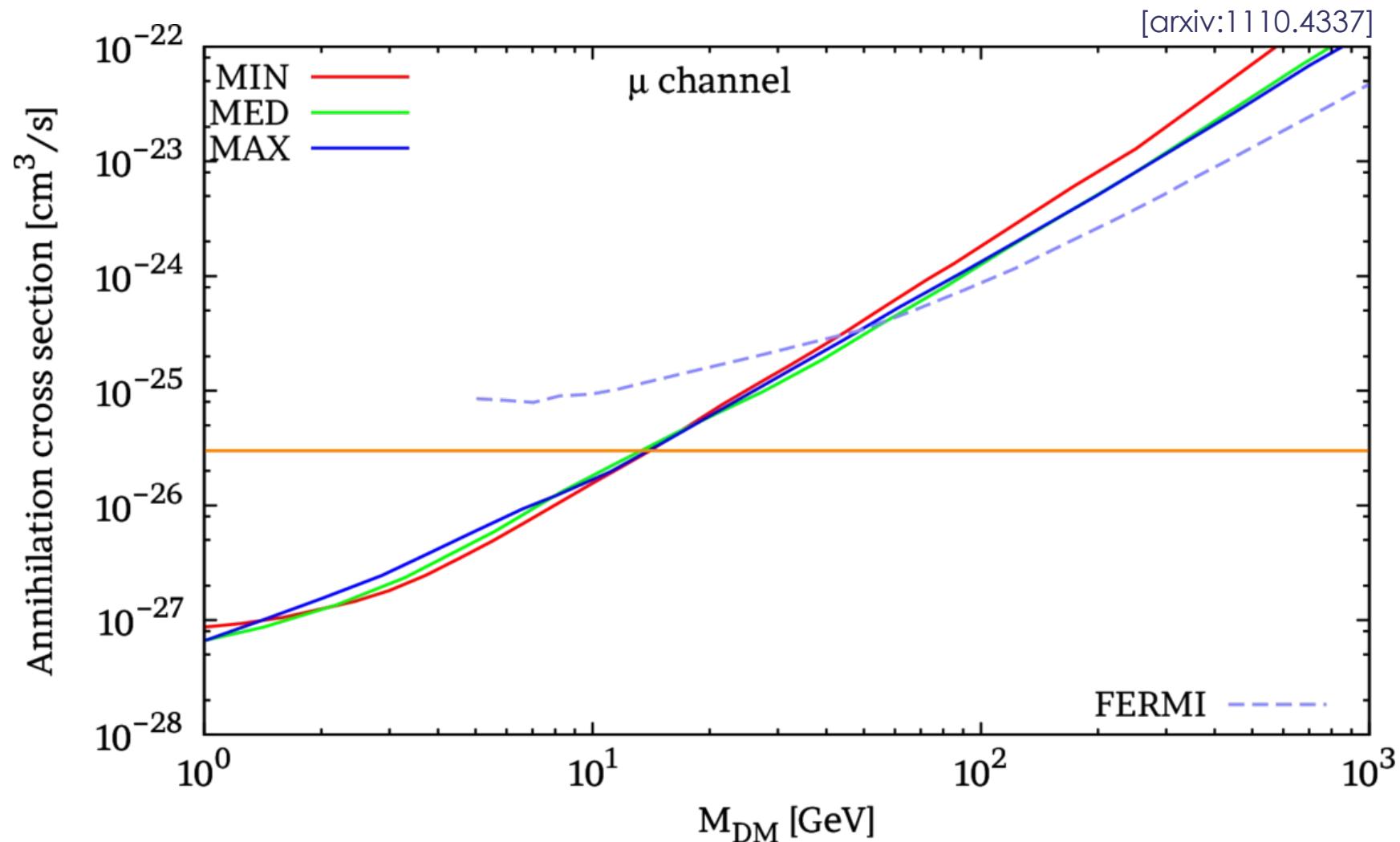
Annihilation into b quarks

[arxiv:1110.4337]



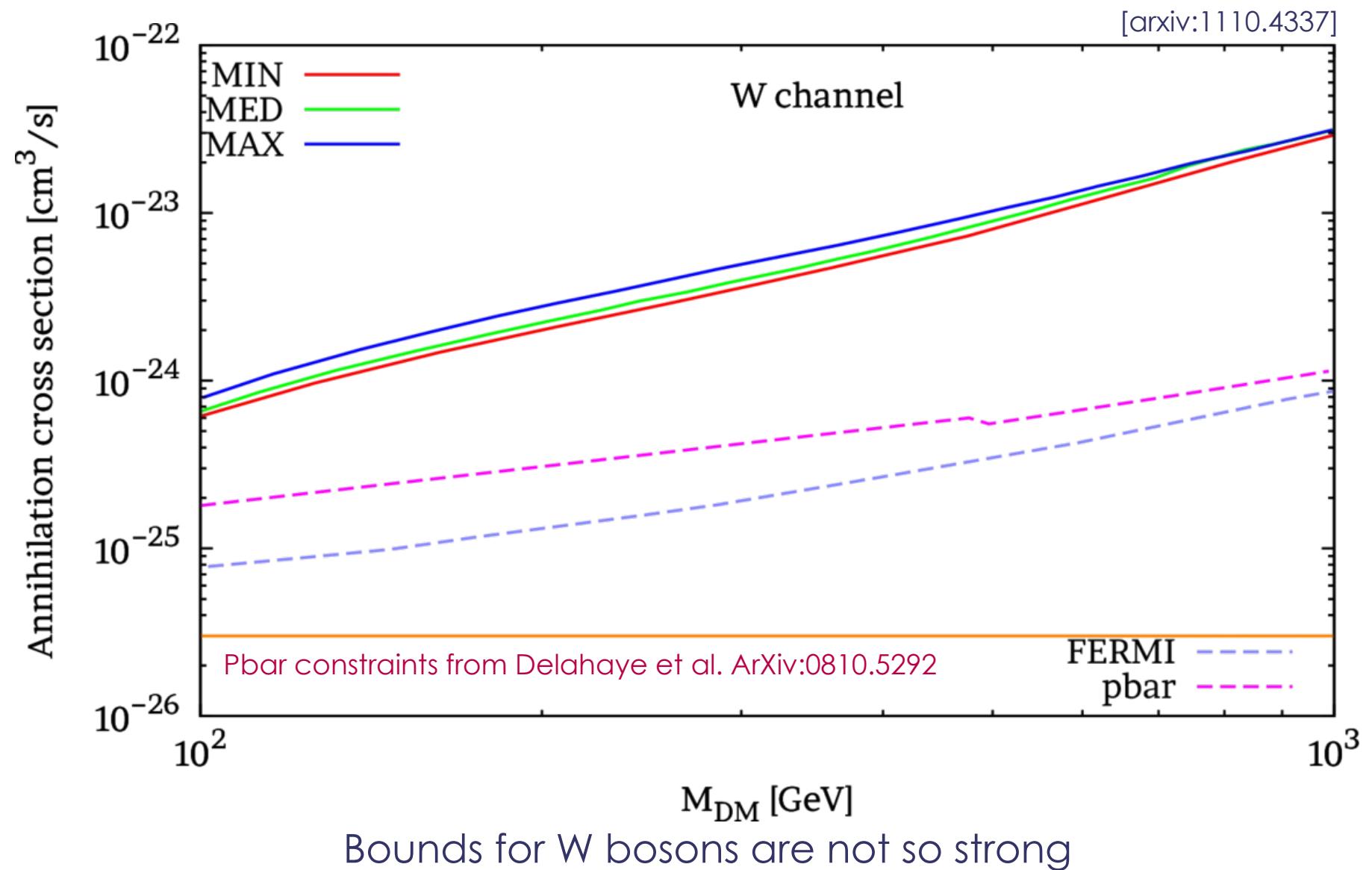
Thermal cross section is reached at ~ 10 GeV

Annihilation into muons

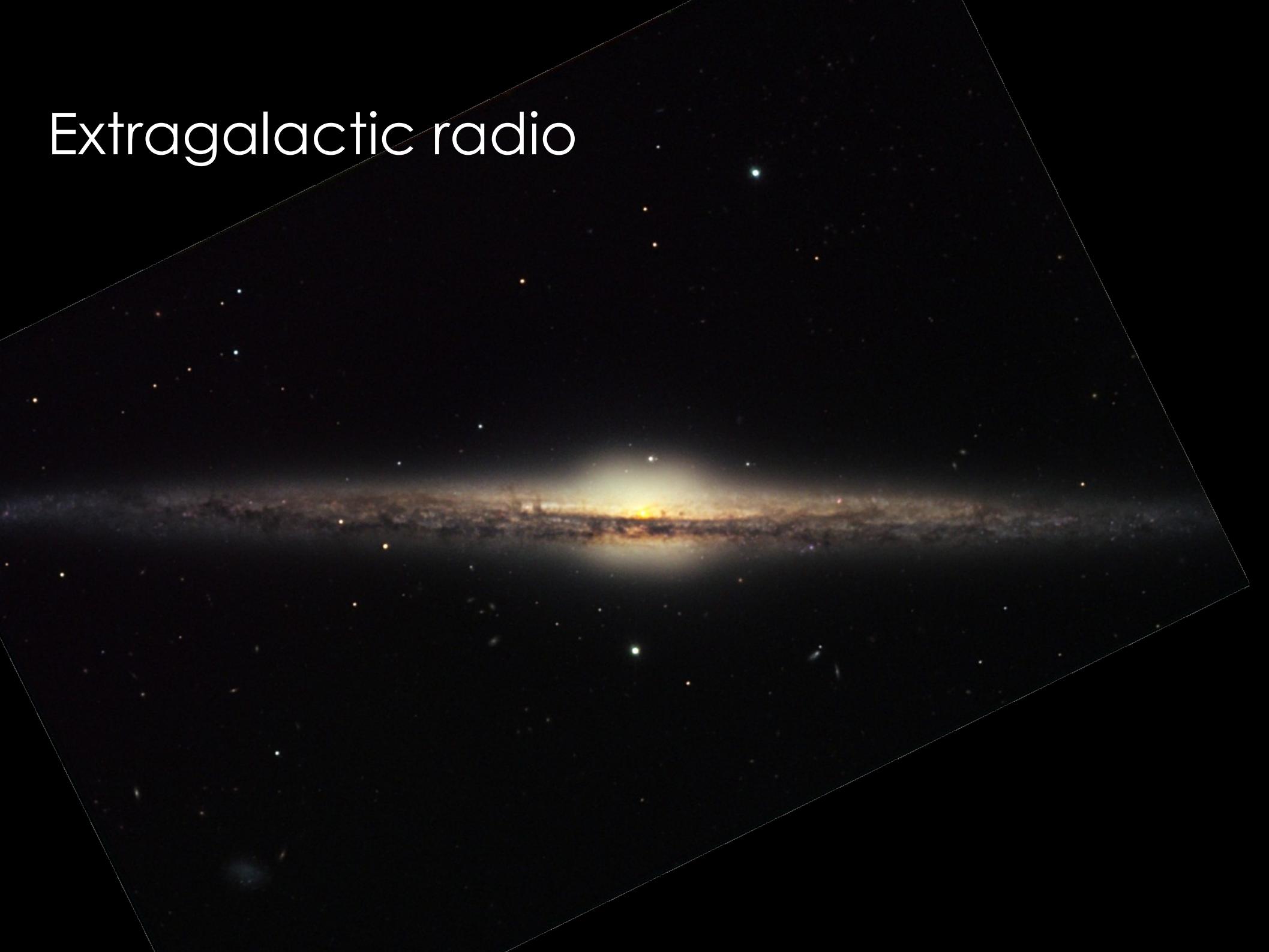


Constraints for DM lighter than ~ 15 GeV

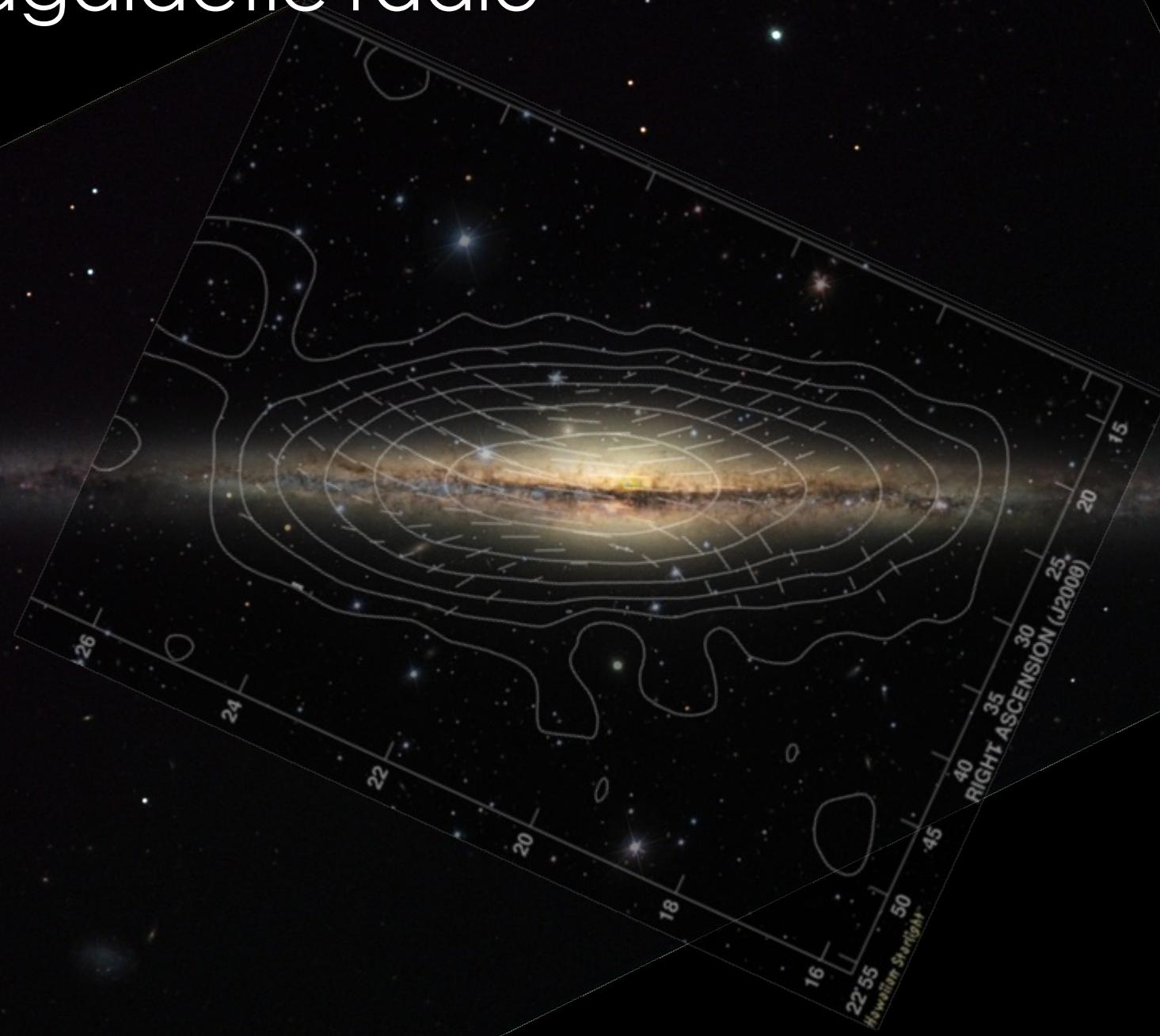
Annihilation into W bosons



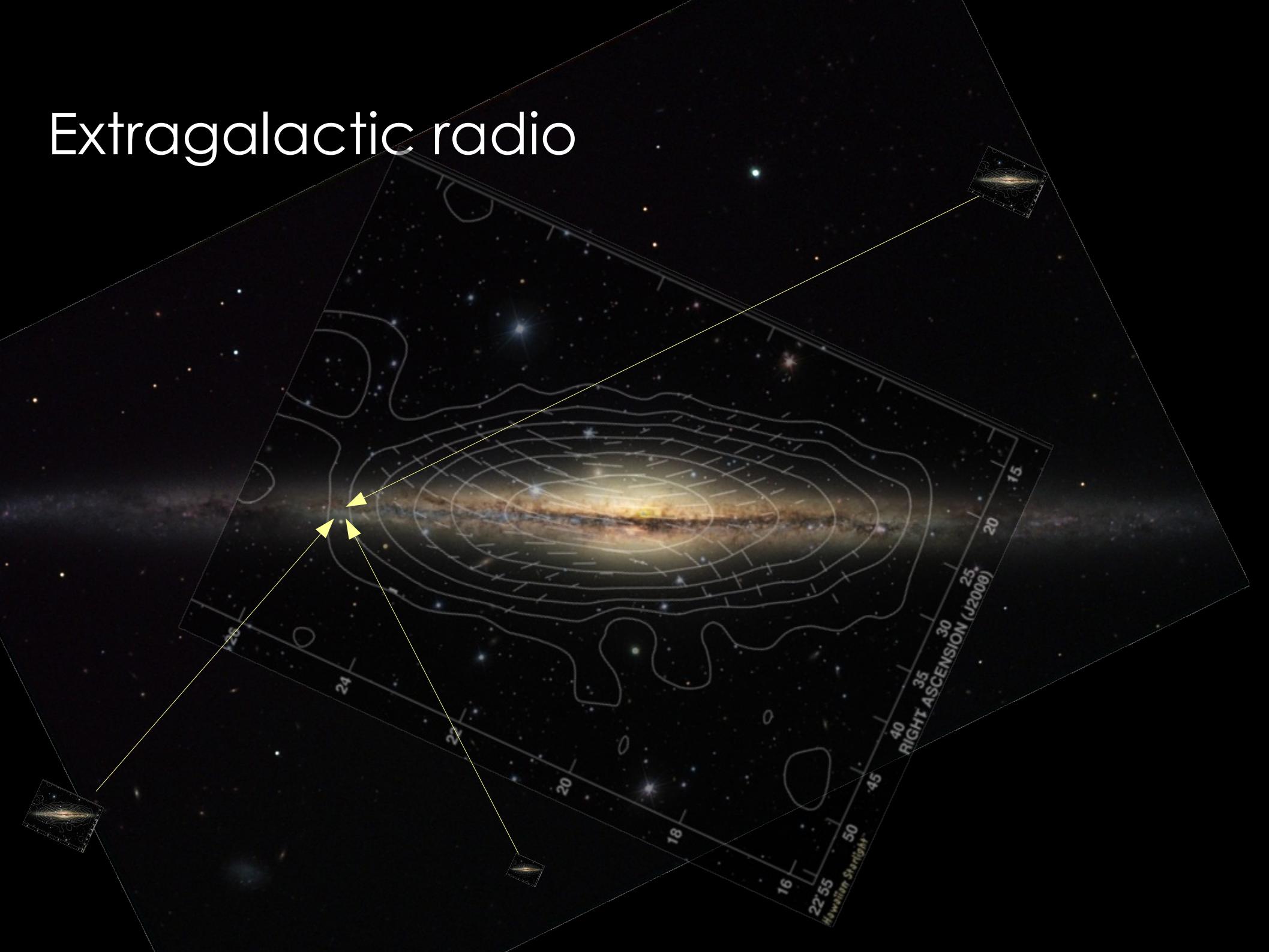
Extragalactic radio

The background of the slide is a dark, almost black, representation of space. It is speckled with numerous small, white dots of varying sizes, representing distant stars. A prominent feature is a thick, horizontal band of light that glows with a warm, orange-yellow hue. This band is brighter in the center and fades towards the edges, suggesting it is a distant galaxy or a cluster of galaxies. The overall effect is one of looking deep into the universe at a time when light from far-off galaxies has traveled through vast distances to reach us.

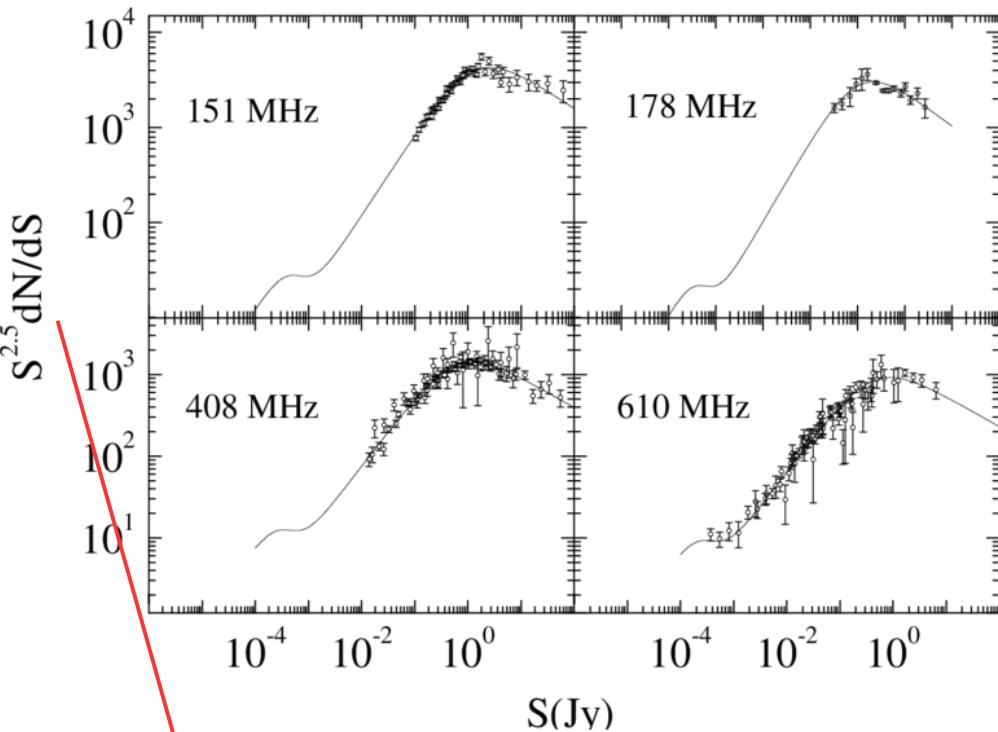
Extragalactic radio



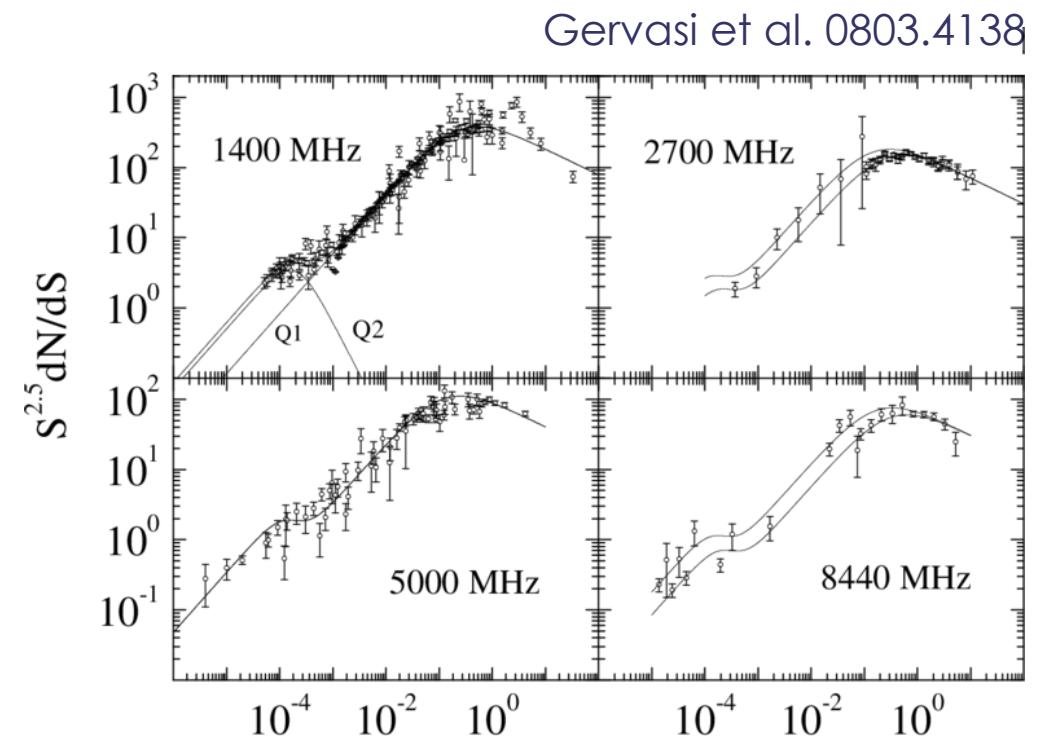
Extragalactic radio



Source Count



Sources per:
unit angle
unit of intensity

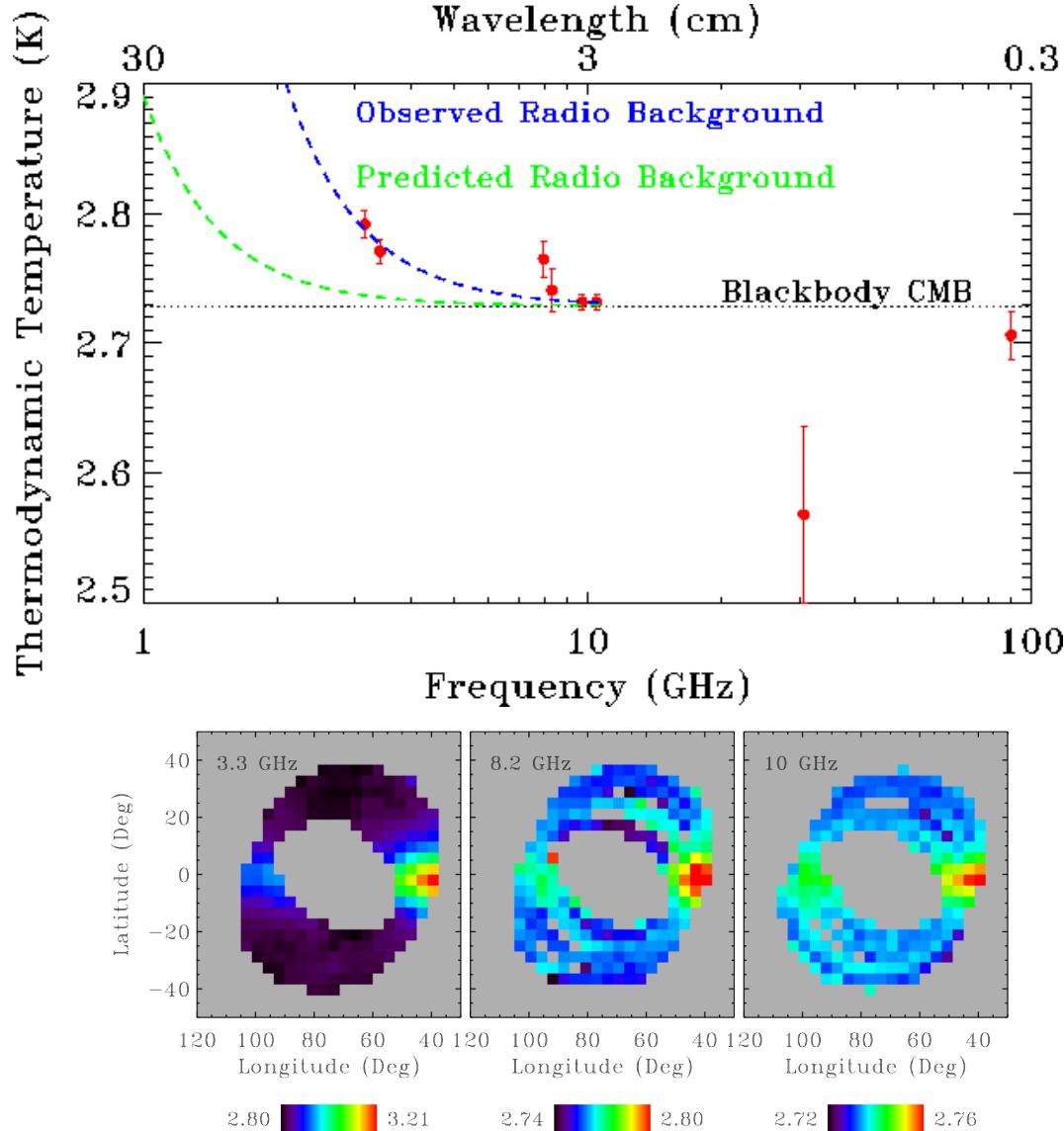


$$\frac{dN}{dS}(S) S dS = \frac{2 k_B}{c^2} \nu_{\text{obs}}^2 dT$$

$$T_E = \int dT = \frac{c^2}{2 k_B \nu_{\text{obs}}^2} \int_0^{S_{\text{max}}} dS \frac{dN}{dS}(S) S$$

Isotropic radio background

ARCADE 2 anomaly



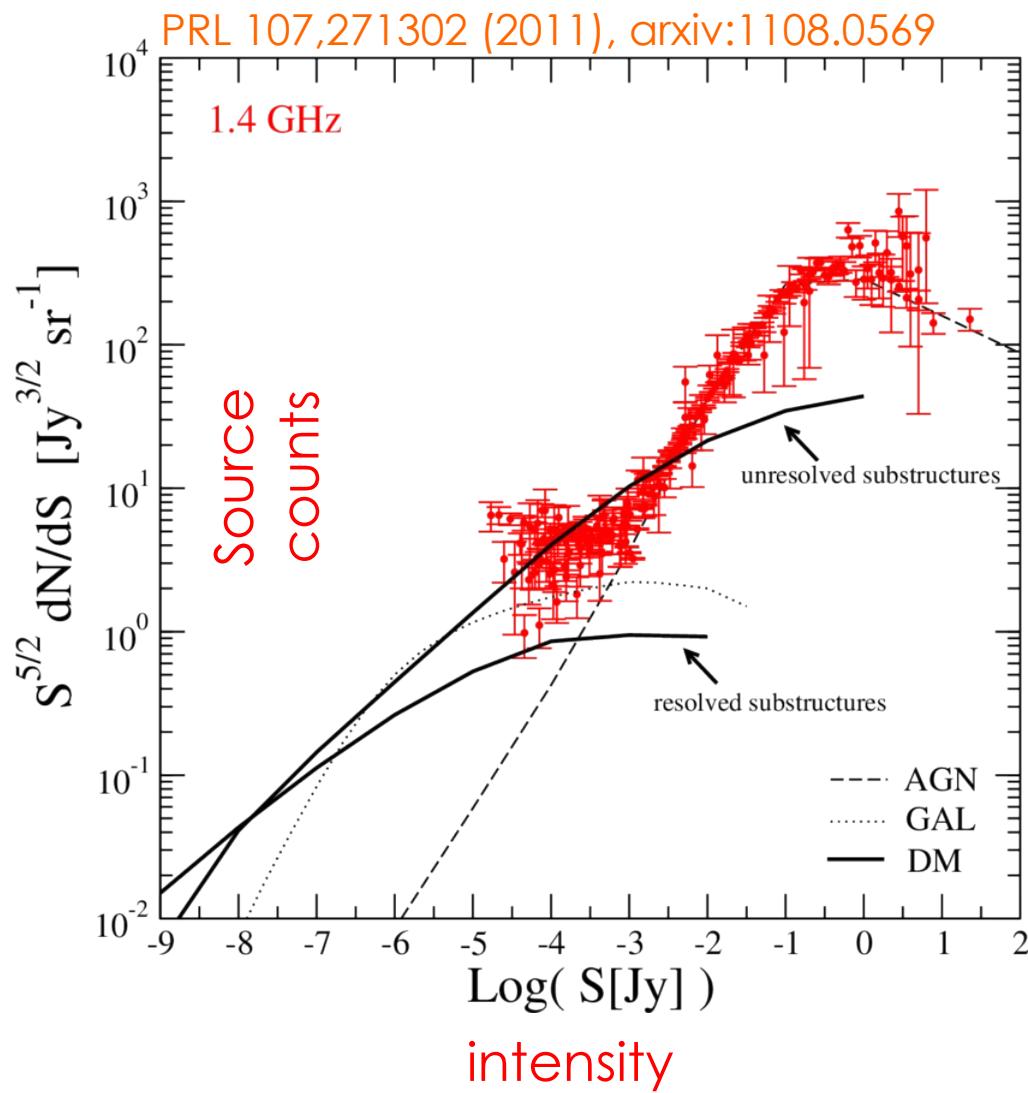
They have reported an excess in the radio background which is bigger than the expected with known sources

$$T_{sky}(\nu, \alpha, \delta) = T_{cmb}(\nu) + T_{gal}(\nu, \alpha, \delta) + T_{UERS}(\nu)$$

Firxen et al. [arXiv:0901.0555]
Seiffert et al. [arXiv:0901.0559]

<http://arcade.gsfc.nasa.gov>

ARCADE 2 anomaly

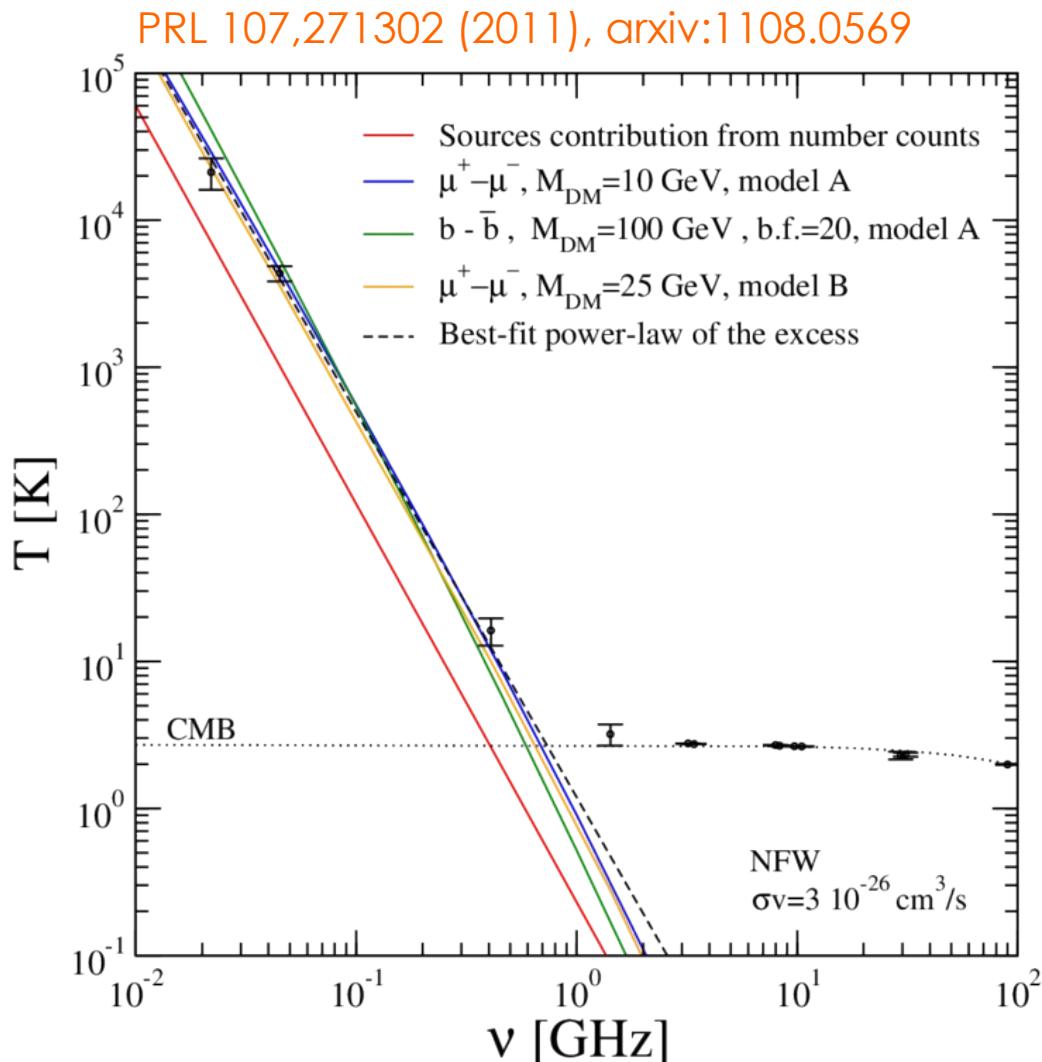


The **source count** is the key to understand the excess

The **ARCADE excess** needs of a extragalactic population of sources that dominates at low luminosity and have a steep radio spectrum

Could **WIMPs** do the job?

ARCADE 2 anomaly



DM can provide the missing signal

However, it is not unique

Alternative explanations

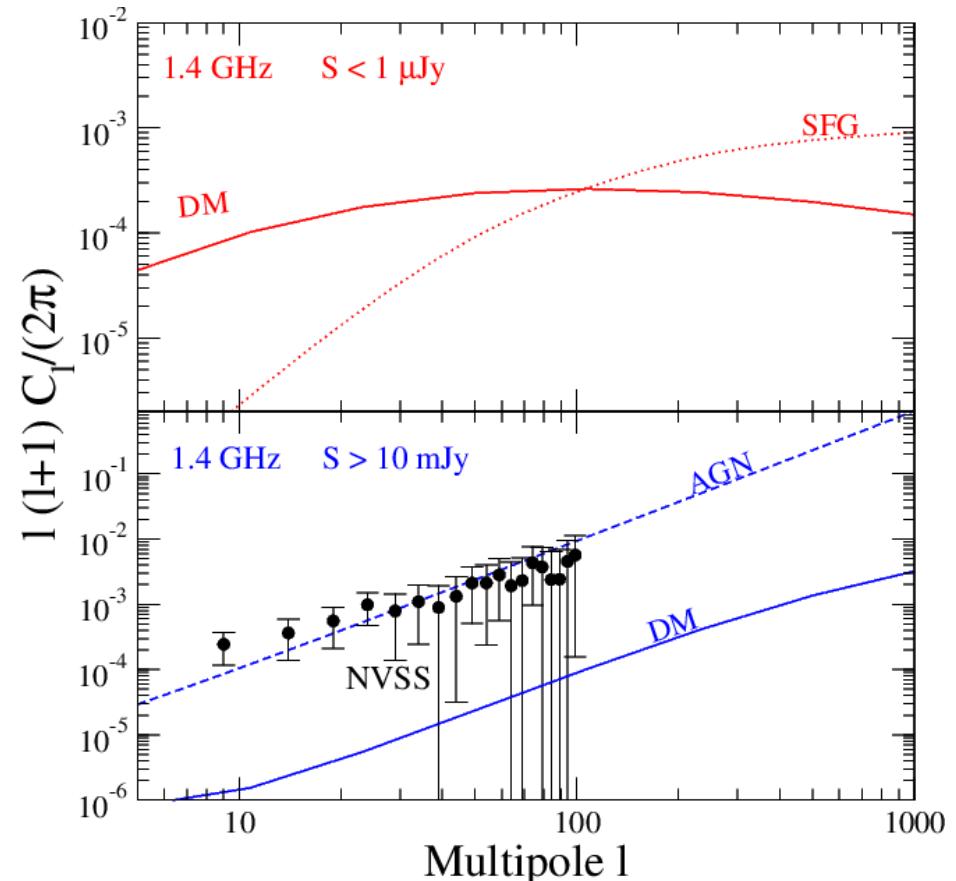
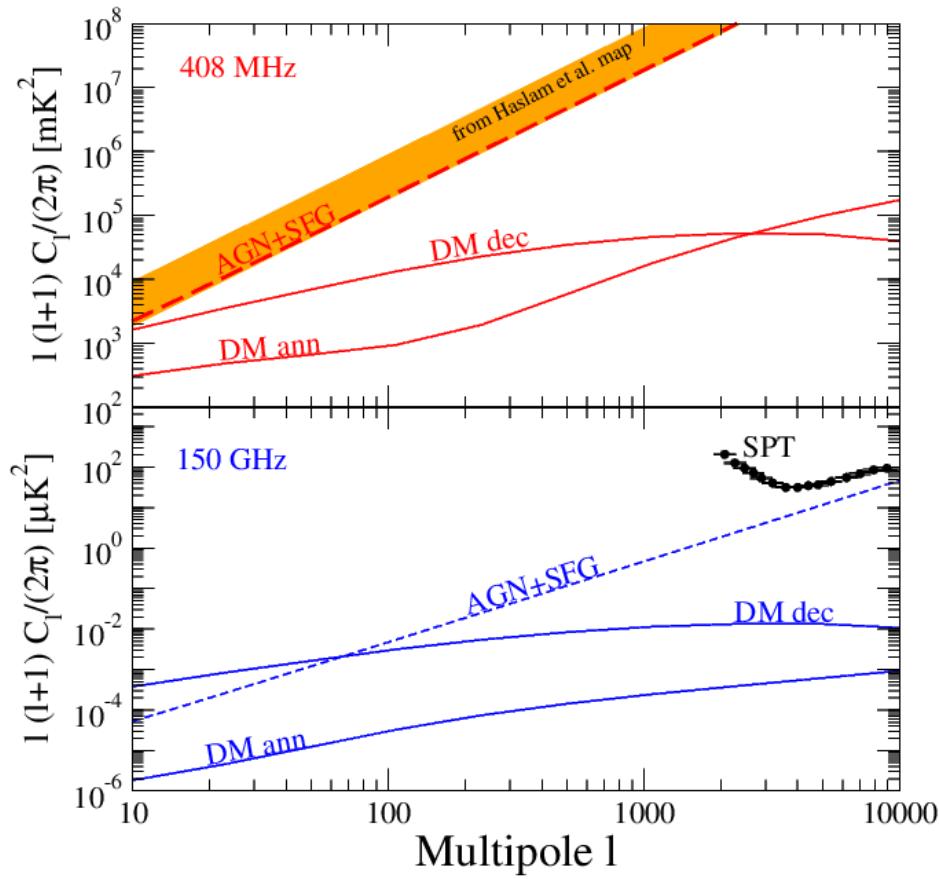
- Faint quasars
- Radio-quite AGNs
- Star forming galaxies
- Unresolved galactic sources(?)

More details:

Gervasi et al. [arxiv:0803.4138]
Singal et al. [arxiv:0909.1997]

Beyond the extra-galactic background

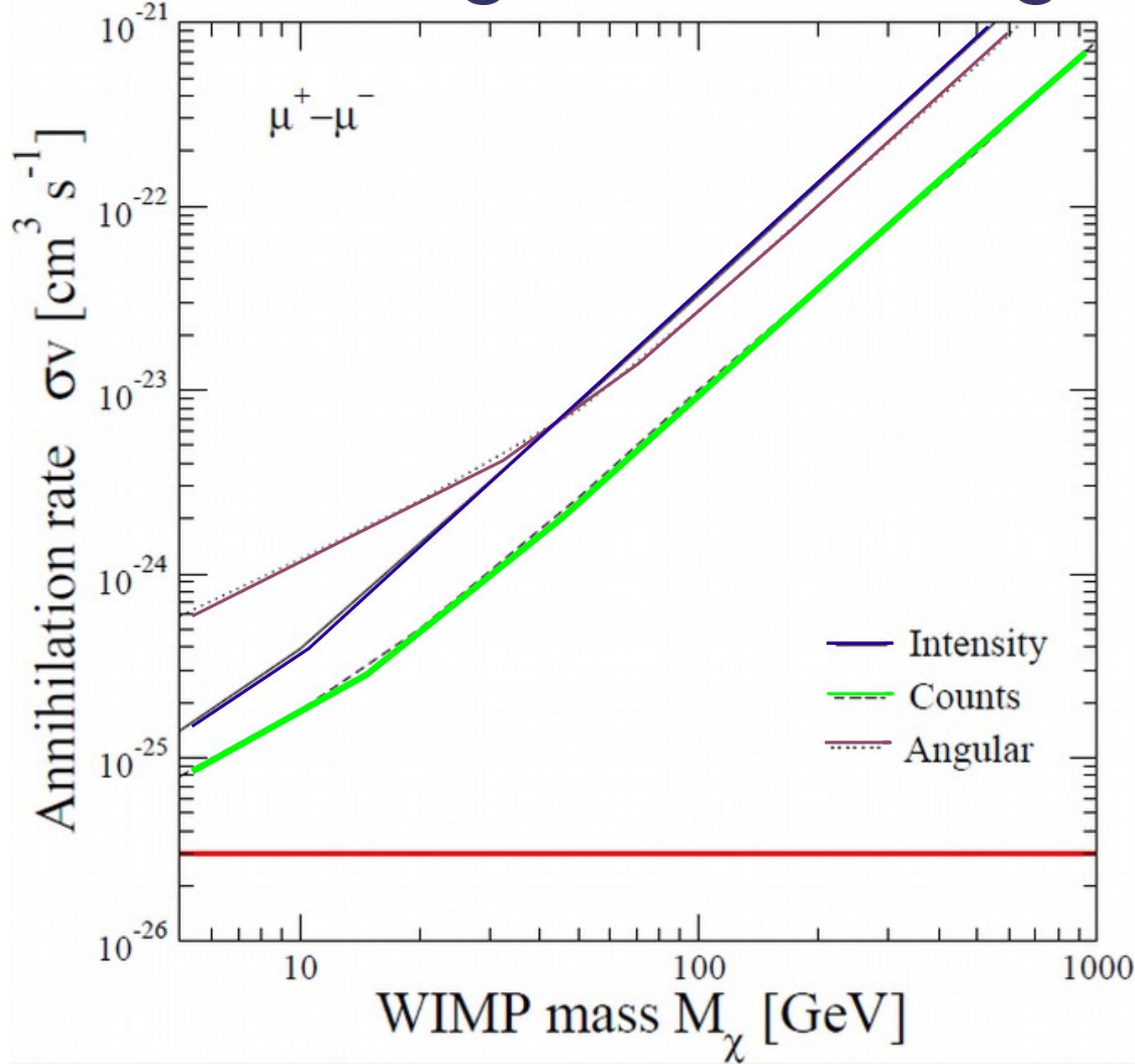
[arxiv:1112.4517]



Power spectrum description of the extragalactic DM radio.
A full analysis and forecast are very challenging

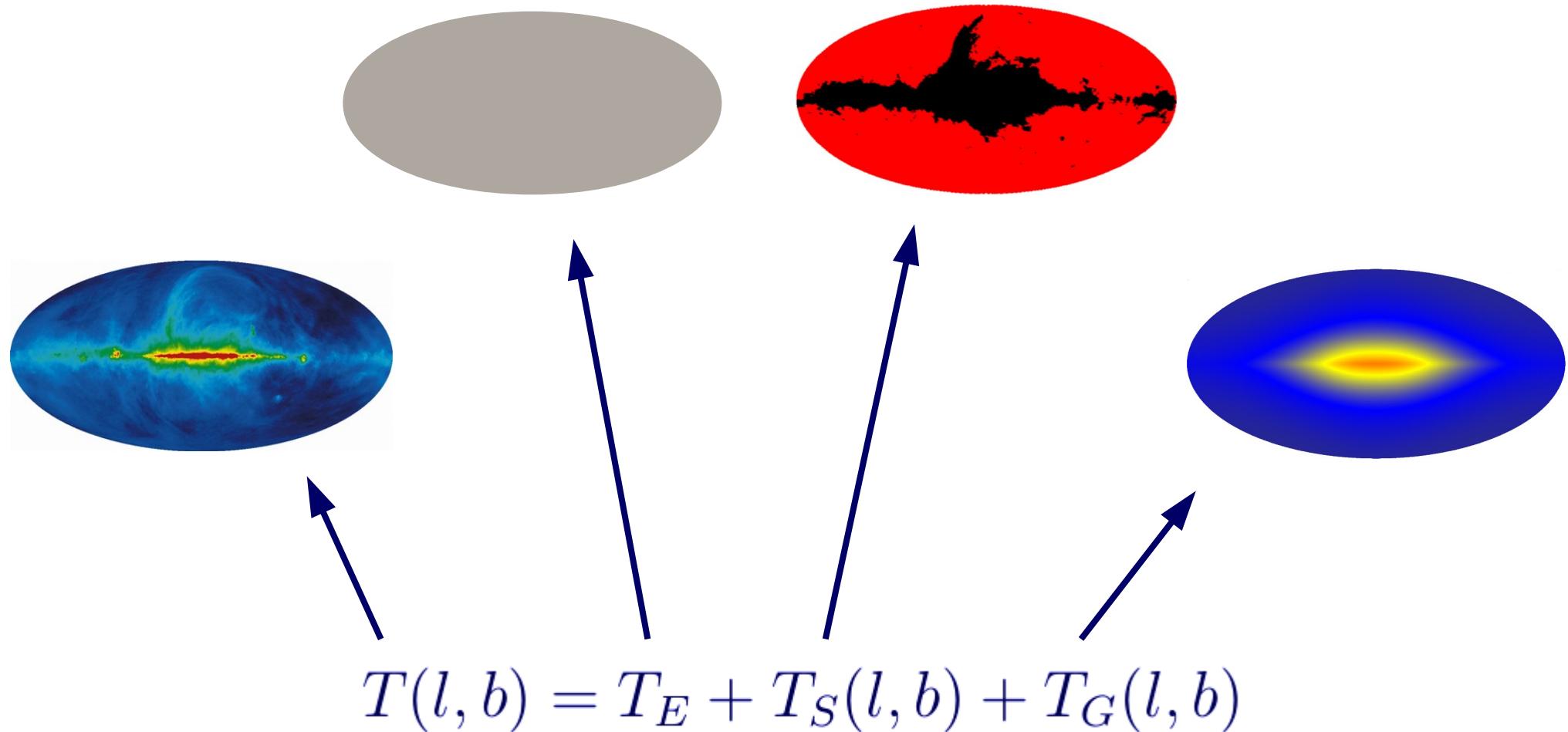
Beyond the extra-galactic background

[arxiv:1112.4517]



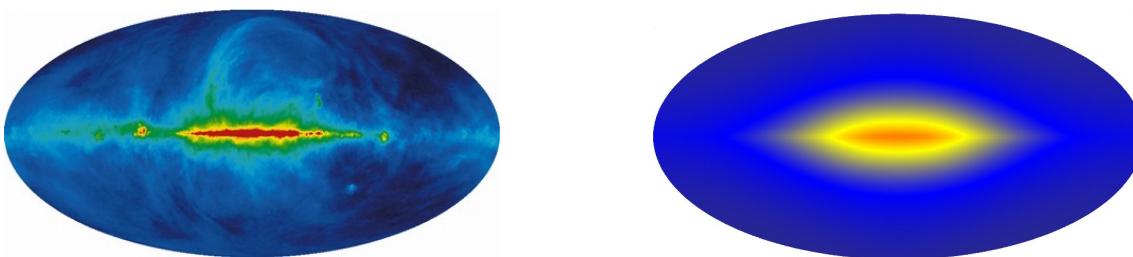
The isotropic radio background revisited

[arxiv:1402.2218]



The isotropic radio background revisited

[arxiv:1402.2218]

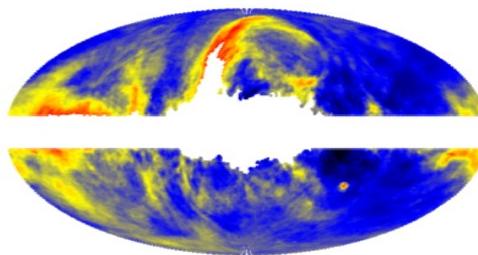


$$T_i^{\text{model}} = T_E + c_{\text{gal}} T_i^{\text{gal,synch}} + c_{\text{brem}} T_i^{\text{gal,brem}}$$

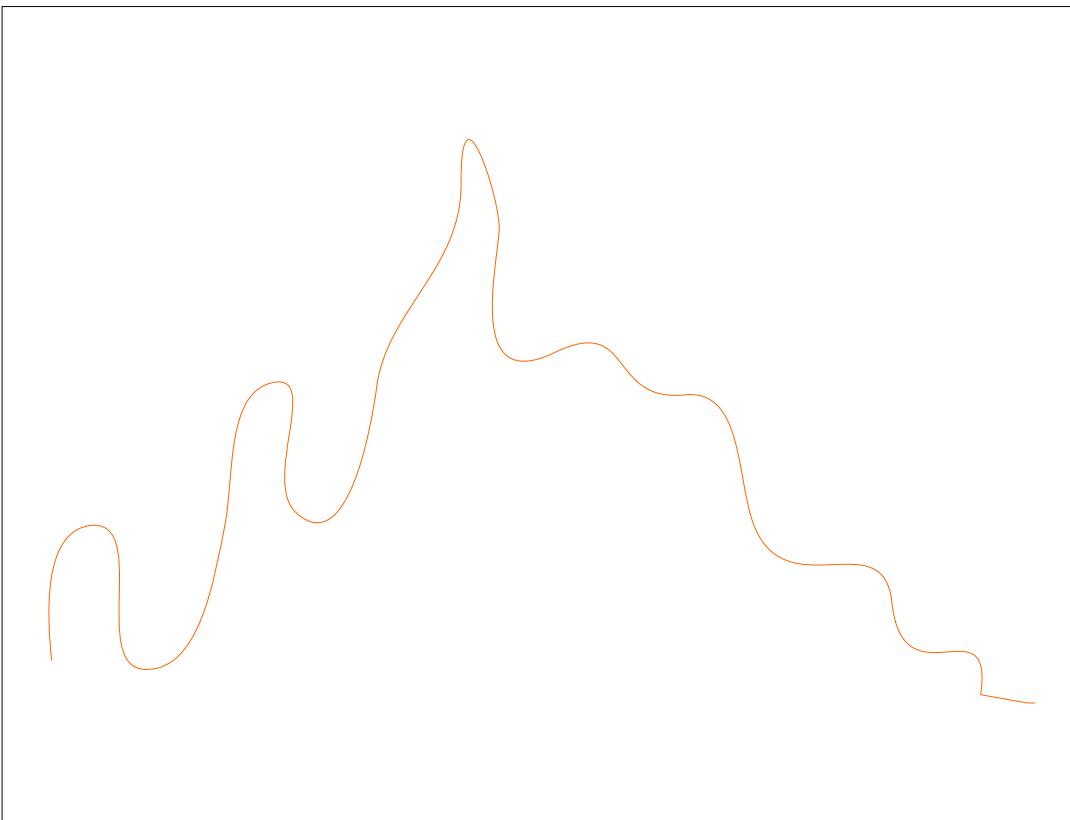


$$R_i = T_i^{\text{data}} - T_i^{\text{model}}$$

$$R_i > T_{R,i} + 5\sigma_i$$

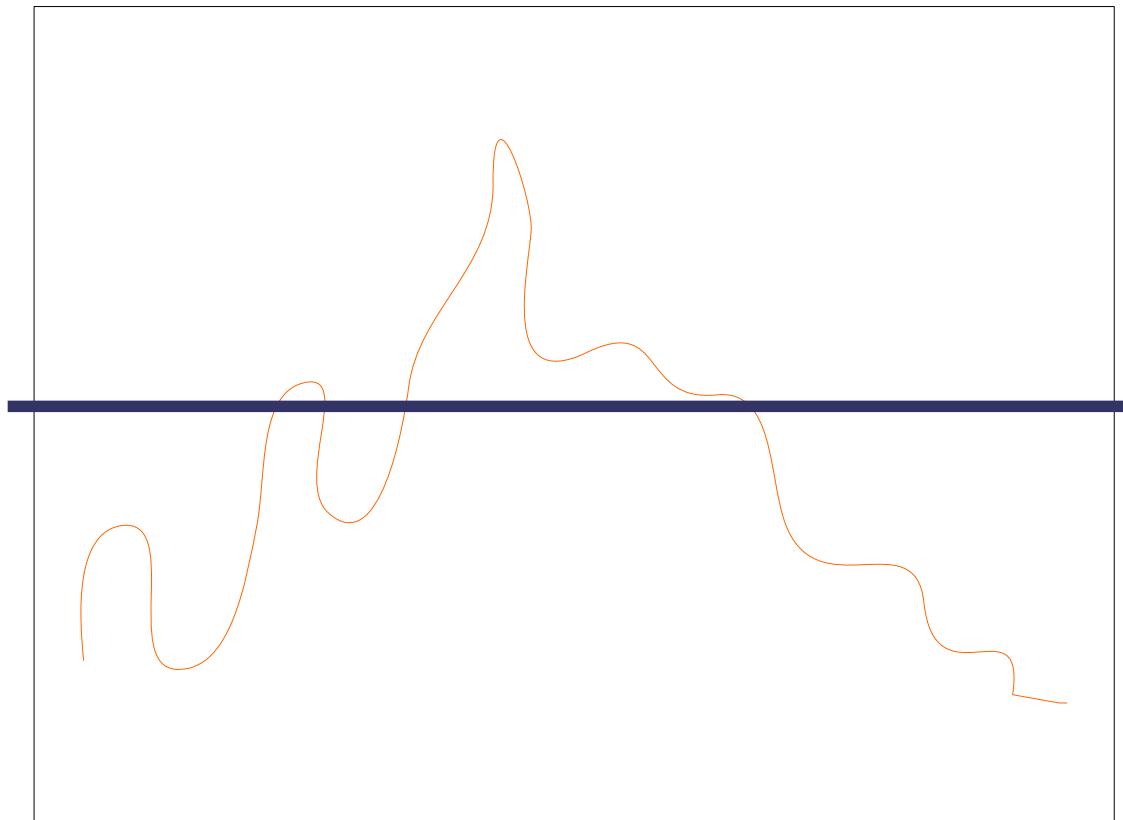


The method



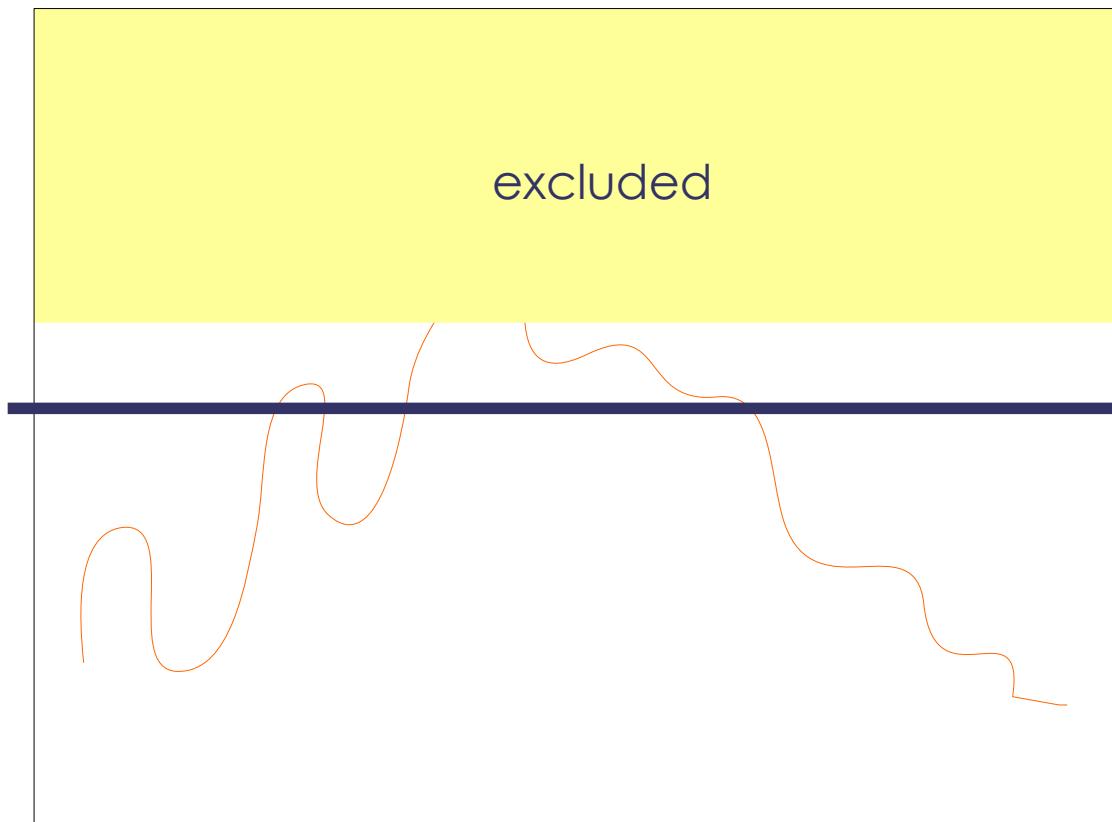
The data

The method

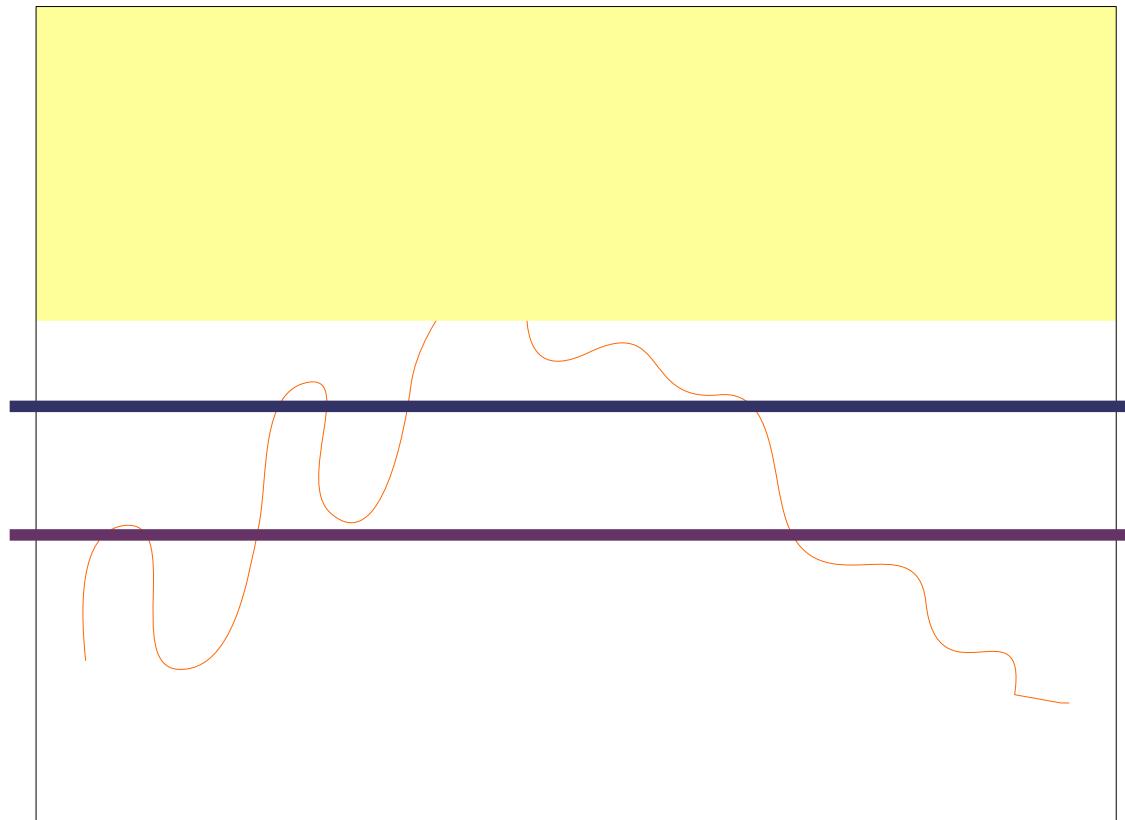


The mean

The method

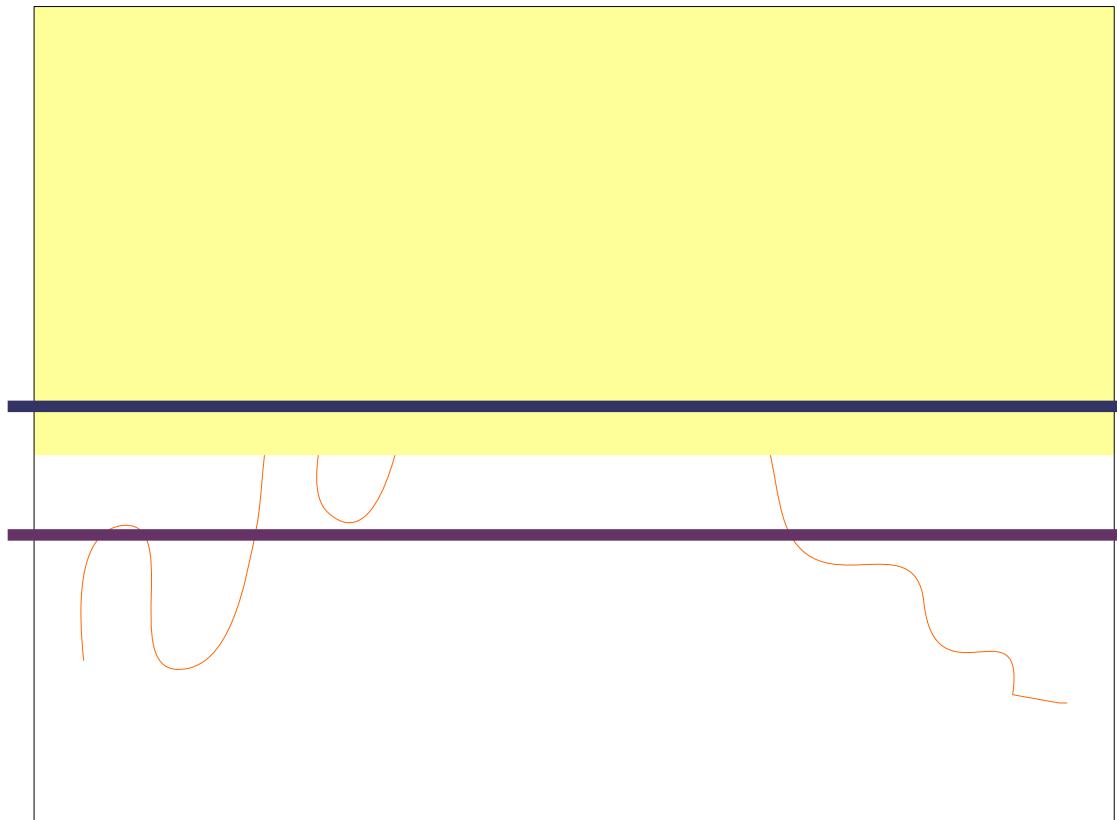


The method



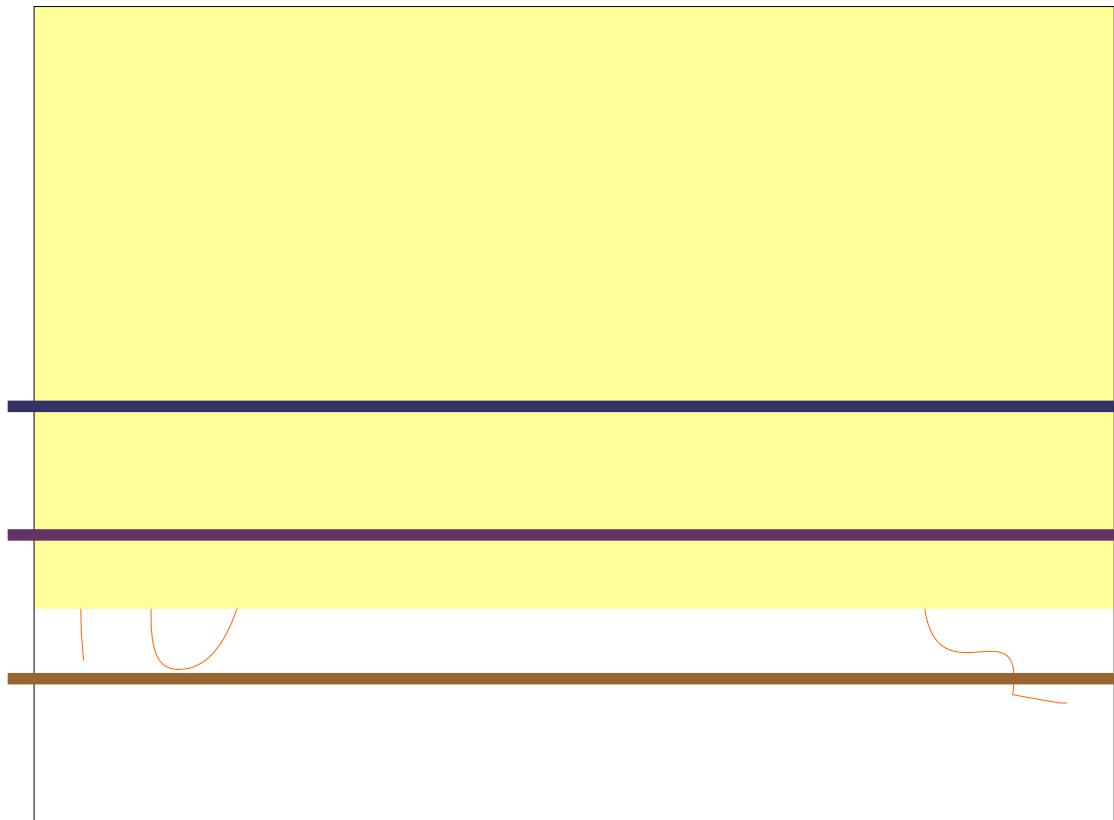
The new mean

The method



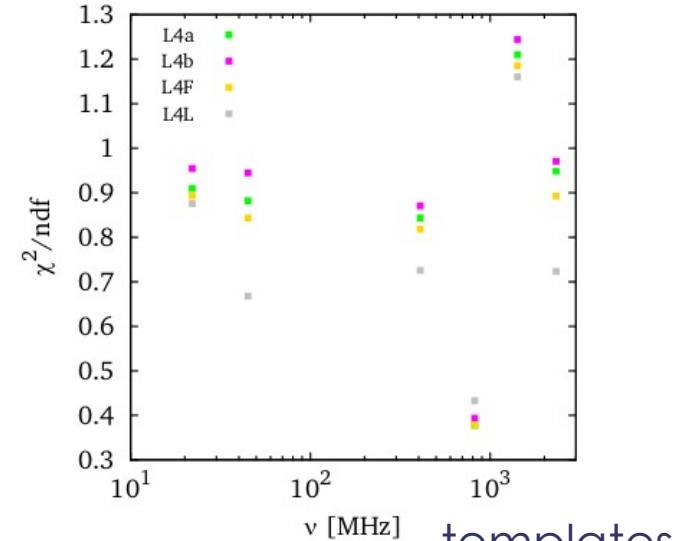
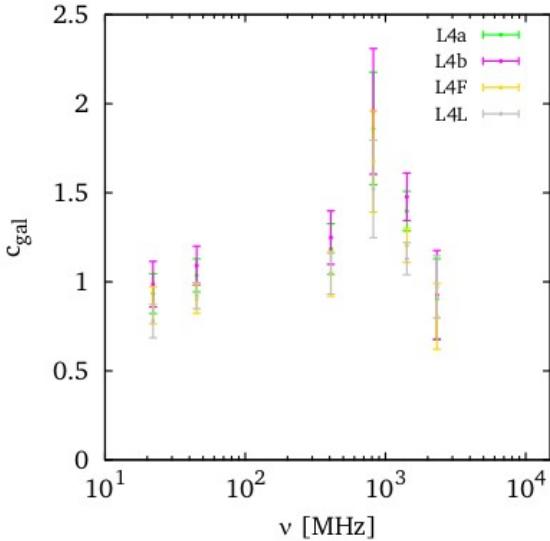
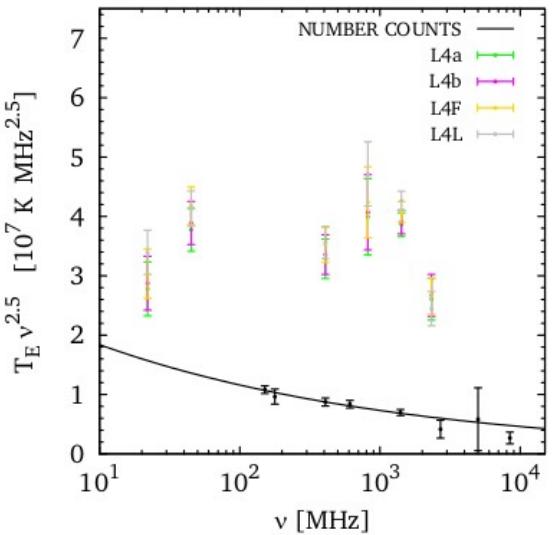
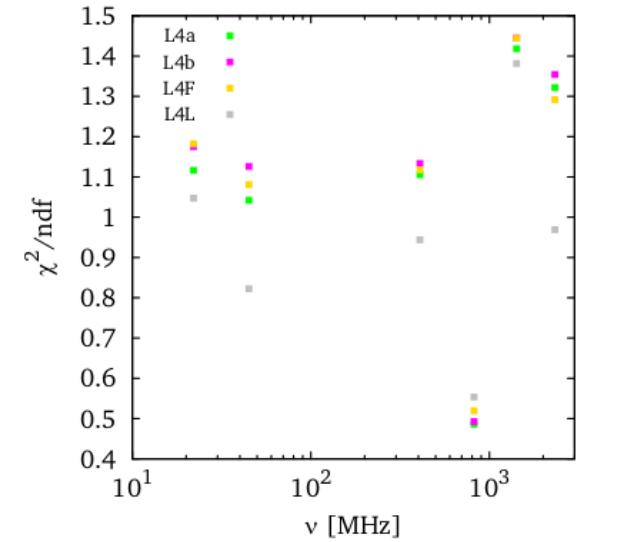
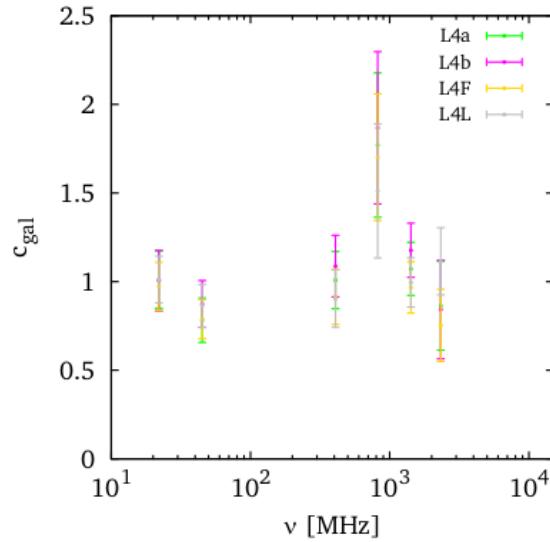
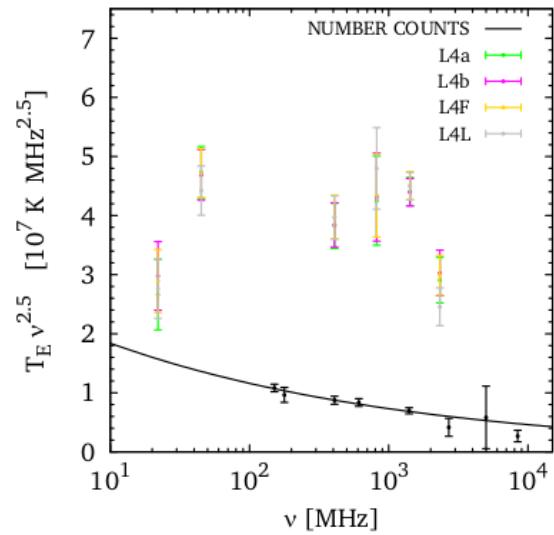
Many iterations

The method



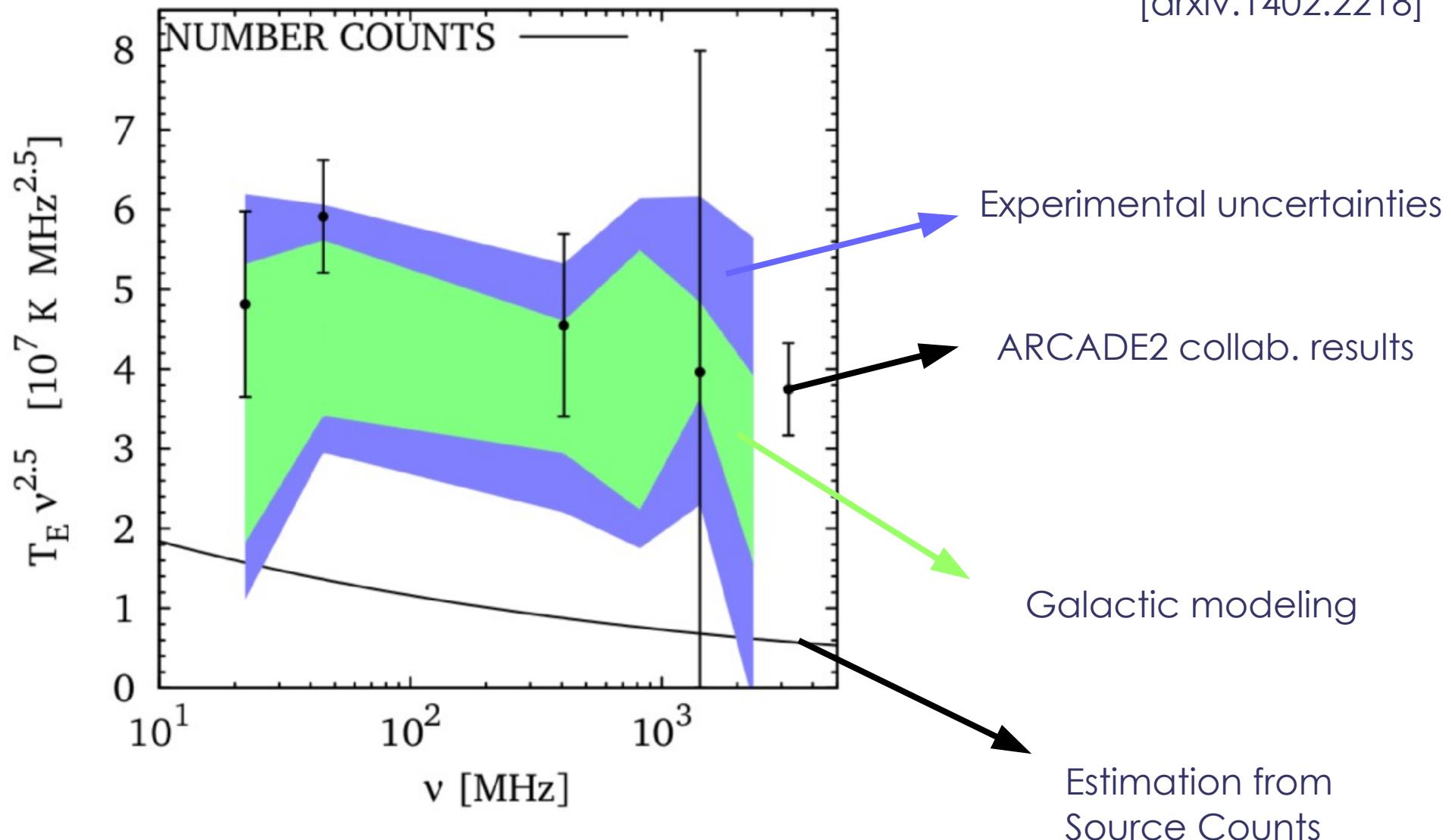
The final estimation
After convergence

Some results



The isotropic radio background revisited

[arxiv:1402.2218]



Conclusions

The (extra) galactic **radio** sky gives an alternative way to constrain WIMP dark matter

DM radio searches are able to explore regions with thermal cross section i.e. $(\sigma v) = 3 \times 10^{-26} \text{ cm}^3/\text{s}$

Lower frequencies are more suitable to explore **light** DM candidates, however cross correlation with other observables are required (!)

The **ARCADE 2 anomaly** is still an unresolved issue

Dark Matter Hunters

Digital resources for hunting the dark sector

The screenshot shows the homepage of the Dark Matter Hunters website. At the top, there's a navigation bar with links to 'Featured posts', 'Publications', 'News', 'Outreach', 'Adv. Search', 'About Us', and 'Home'. Below the navigation is a large figure showing positron flux versus energy. The left panel shows flux vs. energy for different source distances (100 pc, 1 kpc, 2 kpc) with parameters $\alpha = 1.5$ and $\sigma = 2.0$. The right panel shows flux vs. energy for different source ages (0.1 Myr, 0.5 Myr, 1 Myr, 5 Myr, 10 kyr) with the same parameters. A text box below the left plot asks 'What could we learn from a sharply falling positron fraction?' and provides a link to arXiv:1404.7546. Another text box below the right plot discusses neutrino masses due to baryonic feedback processes. On the left, there's a Facebook cover photo of a night sky over telescopes. On the right, there's a Twitter profile for 'DMH' with stats (~1700 tweets, 3,706 photos/videos, 1,966 following, 1,487 followers, 5 favorites). Both sections include links to the science website and social media.

www.dmhunters.org

@DMHunters



www.dmhunters.org/?feed=rss2

15/Dec/2014



[/pages/Dark-Matter-Hunters/130320483778241](https://www.facebook.com/pages/Dark-Matter-Hunters/130320483778241)

WIMP dark matter and the isotropic radio background connection @ DESY, Hamburg

54

Conclusions

The (extra) galactic **radio** sky gives an alternative way to constrain WIMP dark matter

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The **ARCADE 2 anomaly** is still an unresolved issue

Some references

[1106.4821] *Radio data and synchrotron emission in consistent cosmic ray models*
T. Bringmann, F. Donato, R. A. Lineros

[1108.0569] *Possibility of a Dark Matter Interpretation for the Excess in Isotropic Radio Emission Reported by ARCADE*
N. Fornengo, R. Lineros, M. Regis, M. Taoso

[1110.4337] *Galactic synchrotron emission from WIMPs at radio frequencies*
N. Fornengo, R. A. Lineros, M. Regis, M. Taoso

[1112.4517] *Cosmological Radio Emission induced by WIMP Dark Matter*
N. Fornengo, R. Lineros, M. Regis, M. Taoso

[1402.2218] *The isotropic radio background revisited*
N. Fornengo, R. A. Lineros, M. Regis, M. Taoso